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SURF Manual

COMPHIBPAC INSTRUCTION 3840.3

COMMANDER AMPHIBIOUS FORCE
U. S. PACIFIC FLEET
APRIL 1953

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SURF MANUAL

FOR

AMPHIBIOUS PLANNERS

COMPHIBPAC INSTRUCTION 3840.3

COMMANDER AMPHIBIOUS FORCE

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FOREWORD

The SURF MANUAL FOR AMPHIBIOUS PLANNERS is promulgated for information and guidance within PHIBPAC, and should be particularly helpful during the planning and initial operational phases of Amphibious Operations.

This manual is a compilation of the results of much research and study conducted by research organizations under contract to the Department of the Navy, and is presented in a form readily usable by officers and men.

Although the manual was prepared primarily for use by Amphibious Planners it should prove of value, when used in conjunction with SKILL IN THE SURF, to those officers and men most intimately concerned with operation of landing ships and craft in that area crucial in Amphibious Operations -- the surf zone.

As the compilation of data and the research into the effects of surf on Amphibious Operations are far from complete, recommendations for changes or additions based on study and personal experience are invited.

W. M. CALLAGHAN
Vice Admiral, U.S. Navy
Commander Amphibious Force,
U. S. Pacific Fleet

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I. INTRODUCTION

For planning and execution of an amphibious operation, knowledge is required of surf and hydrographic conditions. Studies of both of these features must be conducted because the surf on a given beach depends not only upon beach exposure but also upon the underwater topography. Furthermore the profiles of sandy and gravel beaches are constantly altered by wave action.

Many of the craft employed on amphibious operations are relatively small and, because they must be designed to land upon or across the beach, are not truly sea-worthy in the traditional sense. These craft and amphibious vehicles must operate in the most treacherous regions of the ocean where reefs, sand bars, and surf make boat handling hazardous even though man made obstacles, enemy mines and gun fire are not encountered. During World War II losses of amphibious material caused by the "perils of the sea" probably far outnumbered those caused by enemy action. Two thirds of LCVP and LCM used during the early landing on Sicily broached in the surf. At Iwo Jima the DUKW were unable to mount the steep beach of soft volcanic ash and often broached or swamped in the surf close to the beach. During the first five days, 50% of the DUKW were damaged or lost. On the Normandy beachhead, the landing of urgently needed supplies and equipment dropped to virtually zero during the period when waves were about 8 feet high and nearly 700 craft were damaged or lost. A study covering the first two months of the operation indicated that the tonnage landed varied inversely with the wave height and that when the waves were 5 feet high the amount put ashore decreased to 1/3 or less of that landed during a calm period.

The importance of accurate information of surf conditions to the performance of amphibious craft and vehicles was recognized early in World War II. Extensive oceanographic research and development were concentrated on this problem. As a result new methods of forecasting sea, swell, and surf conditions from meteorological data and detailed hydrographic information off the landing beach were developed. In the invasions of Sicily and Normandy the Axis forces, who had not studied the problem, believed weather conditions to be too severe for a successful landing. The Allies, however, with a more exact knowledge of wave and surf conditions and the capabilities of landing craft, knew differently and by invading according to plan gained the advantage of surprise. At Lingayen the bottom configuration was such that the surf at one part of the landing area could be predicted to be much smaller than elsewhere and the American forces were enabled to take advantage of this fact in the logistic support of the beachhead. Intelligence reports were prepared for the contemplated operations against Japan

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showing beach areas where, owing to the configuration of the bottom, the surf was the minimum for any given wind direction and wave length, in order that rapid forecasts of surf condition might be made immediately prior to invasion.

Since World War II research on Oceanography and Surf and Swell forecasting has continued. Advanced knowledge has resulted in the publishing of H. O. Publication No. 604, "Techniques for Forecasting Wind, Waves and Swell". Investigations have been conducted by the University of California on the characteristics of landing craft in the surf zone; theoretical aspects of the growth of wind waves in deep water; advanced techniques of wave forecasting. Scripps Institution of Oceanography has conducted work on a deep water wave meter which promises additional knowledge of surf conditions during amphibious operations of the future.

The term beach as used in this manual is used in the broader sense, to include both the beach (above LWL) and the hydrography of the bottom adjacent to the beach out to a depth that would affect the formation of breakers and the operations of landing ships and craft in amphibious operations.

II. WAVES AND SWELL

A. RELATIONSHIP OF TERMS

The description of ocean wind waves requires the use of several terms that may not be familiar to all amphibious planners. Thus, the WAVE HEIGHT is the difference in elevation between the trough and crest of a wave; WAVE LENGTH is the distance between successive crests; WAVE PERIOD is the time between the passage of two consecutive crests past a fixed point, and WAVE VELOCITY is the rate of travel of an individual crest. The term WAVE STEEPNESS is defined as the ratio of wave height to wave length.

Since there is considerable variation in wave height and wave length in the waves leaving a generating area, it is necessary to define statistically the significance of the waves. Actually the higher waves are the more important from an operations standpoint; hence in stating the mean height of the waves that exist over a period of an hour or two it is advisable to consider only the highest of the waves that are present. Obviously, every ripple need not enter into forming an average. As a consequence of these considerations the present practice in stating the average wave height is to give the average height of the highest one-third of all observed waves. Where the observation is precise, as in analyzing the records of wave recorders, the average of the highest one-third of the major train of waves is used. This average is called the SIGNIFICANT WAVE HEIGHT.

In addition to these terms which describe the waves themselves there are a group of terms used in describing the conditions under which the waves are originally formed. Thus, the FETCH is the area over which the generating wind blows; the DECAY DISTANCE is the expanse of relatively calm water through which the waves must pass to reach shore; and WIND DURATION is the length of time that the generating wind has been blowing over the fetch.

B. EFFECT OF OCEAN WAVES ON THE AMPHIBIOUS OPERATION

The ocean waves arise from the action of winds both local and far offshore. In general there are two types of surface waves which grade one into the other in such a way that it is difficult to place a limit on either type. First, wind waves are found in a storm area where the waves are being generated. They are usually steep and the time between successive crests is short. Frequently the crests break in deep water. When small, these are called whitecaps and when large they are called combers or breaking seas. In deep water such waves affect the performance of small craft and interfere seriously with navigation of small boats. Second, swell is characterized by a long, smooth undulation

of the sea surface. These waves result from storms at great distances from the coast and the time between successive crests may be very long. Such waves never break in deep water and unless very high do not affect the operation of small craft in deep water except that they may impose heavy stress on gear which is being operated over the side. They do, of course, cause rolling and pitching of large vessels. However, swell is important in that upon reaching shallow water the wave height increases greatly. Thus when they reach a depth shallow enough to break they give rise to an immense surf which may cause damage or destruction to shore installations and make the entrances to harbors impassable. These two types of waves, wind waves and swell, usually exist simultaneously at any time in open water. Swell may be completely obscured by the wind waves and it may be only near shore, when the swell has peaked up to a greater height, that the operator of the craft is aware of the presence of such a swell. To reiterate, it is the swell which ordinarily makes harbors and river entrances impassable to ocean traffic. This swell arising from distant storms approaches the coast at high speeds and in the case of a large offshore disturbance the swell will ordinarily arrive prior to the disturbance, thus ships attempting to reach harbors ahead of a storm may find that the entrance is impassable because of the breaking swell.

C. DETERMINATION OF SWELL FROM WEATHER MAPS

For a locality on an exposed coast, where critical wave conditions result from swell which is generated by storms occurring at considerable distance from the coast, local wind records are of relatively small value in the compilation of significant wave characteristics. Thus where large scale wind patterns are involved there are seldom sufficient weather reports to determine these patterns directly from ship or island observations. There is a very close relationship however, between the wind speed and direction and the atmospheric pressure gradient which can be determined from a weather map. The pressure field is not difficult to determine if sufficient surface weather reports are available. The winds, therefore, are computed from the pressure gradient scaled from a weather map, and wind observations are used to check the computed values. A consideration of the orientation of the isobars on a weather map also permits an estimate to be made of the extent of the generation area and, consequently, the value of the fetch, and the direction of wave propagation.

D. SOME BASIC CONSIDERATIONS OF THE WAVE MECHANISM

The essentials of energy input into the wave mechanism are the velocity of the wind, its duration and the fetch. The wind direction determines the locality of eventual wave attack. The important characteristic of the transporting mechanism is the distance of decay. The

nature of their attack depends upon their direction, period and upon the shoreline configuration. The degree of attack and overall rate of energy output is a function of their height and period.

In general, the longer the fetch, the higher will be the waves and the greater their period, length, and velocity. For a particular fetch and wind velocity, however, there is a maximum wave height and period that can be developed regardless of the duration of the wind. In a generating area the waves are steep and short crested with many of them breaking as whitecaps. After leaving a generating area the wave length, period and velocity gradually increase. The shorter waves possess relatively little energy and soon disappear, but the longer waves become more regular the farther they travel and, in the case of some ocean waves, may travel thousands of miles from the generating area before breaking on a distant shore.

There have been many times when waves generated at a distance of over 3,500 miles have reached a coast with sufficient size to give breakers up to about 10 feet in height. On the Southern California coast waves from storms in the Southern Hemisphere, almost 5,000 miles away, have been observed on numerous occasions.

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III. SURF AND THE SURF ZONE

A. INTRODUCTION TO CERTAIN TERMS

In order to describe the different types of surf which may be encountered, a number of terms will be further explained:

1. The SURF ZONE is the area extending from the outer breaker line (the outermost breakers) to the limit of the uprush on the beach. A wide surf zone offers less hazards to landing craft than a narrow surf zone, other conditions being equal.

2. The WAVE LENGTH is the horizontal distance between two successive wave crests.

3. The PERIOD of the breakers is the time interval between two successive crests passing a fixed point. For long period waves the wave length is long. Directly outside the breaker line the wave length varies between 100 feet and 300 feet as the period varies from 6 to 16 seconds.

4. LONG PERIOD WAVES offer less hazards to landing craft because the distances between crests are greater and the time interval between breakers is longer.

5. The HEIGHT OF THE BREAKER is the vertical distance from the crest of the preceding trough. The breaker height depends on the height of the deep water waves and on the topography of the sea floor. The deep water waves that advance from any wind area are not uniform but comprise trains of waves of different periods and different heights, such that high and low breakers follow each other in more or less regular succession. An attempt should always be made to report or forecast the significant breaker height. The highest breaker in a ten to fifteen minute period can be expected to be about 1.3 times higher than the significant or forecast value. Hazards to landing craft increase with increasing breaker height but the difficulties encountered depend also upon the width of the surf zone, the period of the waves, and the type of breakers.

6. WAVE STEEPNESS is the ratio of wave height to wave length, and varies from 1/7 to less than 1/100, and may also be expressed as decimal fractions.

7. FOAM LINES (foam crests) travel toward the shore when the wave has broken. Their speed decreases with depth in the same manner as wave speed.

8. REFRACTION is the bending of the crest of a wave which occurs when one portion reaches shallow water, and the remainder, still in deep water, speeds on, with the result that the wave crest swings around and tends to become parallel to the coast line.

B. BREAKER TYPES

1. Plunging and Spilling Breakers

Perhaps the most important difference between breakers of similar height is the overall manner in which the breaking takes place; that is, whether the breakers are plunging or spilling or of an intermediate type. In a plunging breaker the energy which the wave has transported across many miles of sea is released suddenly into a downwardly directed mass of water and is dissipated into heat by turbulence. In a spilling breaker the energy is not so instantaneously released but rather the breaking process takes place over a considerable length of time and over a considerable part of the breaker in its travel towards the beach. Thus an amphibious craft in the surf is subjected to a far greater impact when meeting a plunging breaker than when meeting a spilling breaker.

In the plunging type, the wave peaks up until it is an advancing vertical wall of water. The crest then curls far over and descends violently into the preceding trough where the water surface is essentially horizontal. Considerable air is trapped in this process and this air escapes explosively behind the wave, throwing water high above the surface. The plunging breaker characterized by a loud explosive sound and the character of the surf can often be ascertained when it is not visible for reasons of fog or darkness. The spilling breaker on the other hand, is characterized by a breaking process wherein the wave peaks up until it is very steep but not vertical. Only the topmost portion of the crest curls over and descends not on the preceding trough as in the case of the plunging breaker but rather on the forward slope of the advancing wave where it then slides down into the trough. This process starts at scattered foci which coalesce until the wave becomes an advancing line of foam. As previously stated the process takes place over a considerable length of time and over a considerable distance.

2. Surging Breakers

Another type of breaker which is less frequently observed is the surging breaker. In this case the wave crest tends to advance faster than the base of the wave to suggest the formation of a plunging breaker. However, the wave base then advances faster than the crest, the plunging is arrested, and the breaker surges up the beach face as a wall of water which may, or may not be white water.

The Causes of Plunging and Spilling Breakers

As ocean swells or waves approach the shore they peak up to a greater height. The wave length becomes greater and the crest becomes

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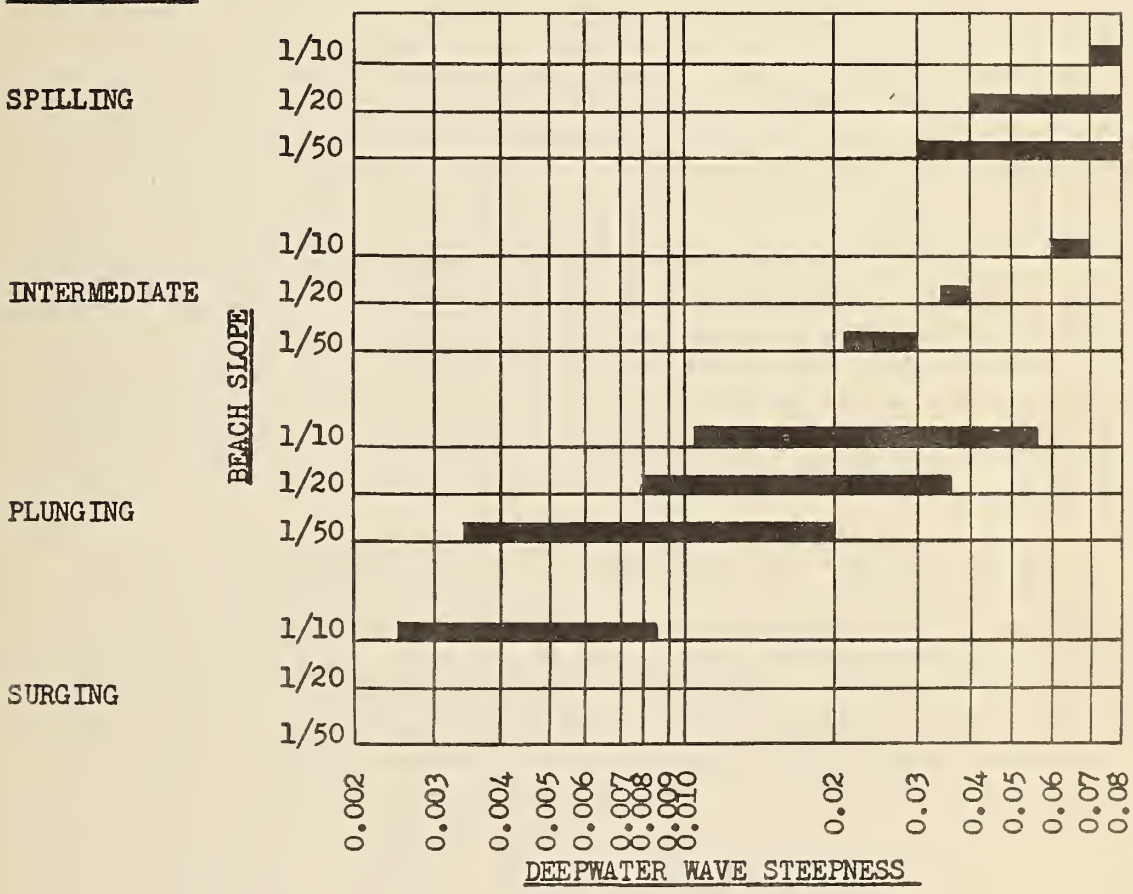
GRAPH SHOWING RELATIONSHIP OF DEEPWATER WAVE STEEPNESS TO

BEACH SLOPE IN THE FORMATION OF DIFFERENT TYPES OF BREAKERS



Deepwater wave steepness $\frac{H_o}{L_o}$ $\frac{\text{Wave height in deepwater}}{\text{Wave length in deepwater}}$

Example: If the deepwater wave height is 4.0 feet, deepwater wave length is 50 feet and beach slope is 1/10; dividing the wave length into the wave height will give a ratio of .08, which is the wave steepness; entering the graph with a beach slope of 1/10 and a wave steepness of .08 the breakers will be of the spilling type.

FIGURE 1.

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narrower and higher. The longer and lower a wave is, the more it will peak up as it advances into regions of shoal water. Thus storm waves which have a relatively short wave length and great height do not peak up to a much greater height prior to breaking. Figure 1 on page III-3 illustrates the relationship between beach slope and the ratio of deep water wave height to deep water wave length. It must be realized that this is an ideal presentation of the relationship and does not consider such influencing factors as refraction, offshore bars, etc. During the process of peaking up as the waves enter shoal water they become progressively more stable. When a wave plunges the ultimate condition of instability has been reached simultaneously by a considerable length of crest and thus a great length of the wave crest curls over and descends in the manner previously described. If however, during its entry into shoal water a wave is subjected to disturbing influences, certain small portions of the crest become unstable prior to the time that the entire length of the crest has reached a similar condition. These small parts then may start to break but are impeded by the effect of adjacent regions which have not yet become unstable. The breaking then is of a spilling nature in which only short parts of the wave crest break and the general effect is a much less violent process. The disturbing influences which may result in spilling breakers are superimposed short period wind chop arising from local winds, reflected waves from nearby rocks, or bottom irregularities.

Storm waves are not only inherently more likely to spill when they reach shore but are also more likely to be disturbed because of the presence of short choppy waves existing in this disturbed region. Long swell on the other hand frequently will reach the coast during calm windless weather. Long swell is inherently inclined to produce plunging breakers and also will be likely to do so because of the probable absence of disturbing wind waves at the time of their arrival. Winds blowing towards the sea destroy short period waves from local sources but permit the passage of long period swell. Thus when the wind is offshore, ideal conditions exist for the production of plunging breakers. In addition to this there seems to be an aerodynamic condition resulting from the waves causing them to plunge even more violently under this situation than they would if no offshore wind were present. The wave seems to pass the normal breaking point and peak up to a greater height before breaking when the wind is opposing.

The Causes of Surging Breakers

Breakers are more likely to plunge or surge on steeper beaches. High backwash velocities promote the retardation of the base of the advancing wave to establish the plunging tendency. When the backwash depth becomes too small the retardation is not effective and the advancing wave tends to surge.

C. EFFECTS OF BEACH PROFILE ON SURF

There is some greater tendency for plunging breakers to occur on the steeper beaches than on flat beaches. This seems to be due to the fact that as a wave advances upon a beach of steep gradient there is less time spent in attaining an unstable condition and consequently less opportunity for disturbing conditions to initiate a spilling process. In addition to this, flat beaches are frequently of an irregular profile and the bottom irregularities result in the production of spilling breakers at most points along such a beach. When strongly plunging breakers occur upon beaches of flat profile it has been noted that this is associated with an unusually regular beach or the occurrence of a temporarily steep section of the beach profile in the breaker zone. In this connection beaches in partly protected bights, bays and estuaries which are subjected only to waves that have undergone considerable refraction or diffraction almost invariably produce plunging breakers. In this case the beach profile is normally very regular, disturbing influences are at a minimum, and the short period wind waves have been screened out. Although not practical for planning purposes, it is possible for a surf condition to be modified by the creation of a secondary disturbance when the surf is of a predominately plunging type. This might be accomplished by artifically generating a secondary disturbance and altering the breaker type. It has been noted in observing amphibious landings that a surf consisting primarily of plunging breakers was so altered by the bow waves of the landing craft which set up a modified region in the surf. A heavy plunging surf has sometimes become passable during the first two or three hours of a storm due to the alteration of breaker type by wind waves. As in other natural processes the energy required to "trigger" the release of wave energy is small. The breaker height and the breaker type are most important surf factors in judging the feasibility of an amphibious operation on any beach. There are several other factors, however, which enter into the condition of the surf as regards such an operation.

D. THE EFFECT OF BREAKER ANGLE ON LANDING CRAFT

The angle at which the waves break in respect to the general shoreline contours imposes a number of complications to an amphibious operation. Long period waves reaching a beach of normal slope will undergo such refraction that there is rarely any appreciable angle apparent at the breaking point. Short period waves, wind waves and chop do not undergo any great change of direction in approaching a beach and if their deep water angle of approach is not normal to the beach they will break at an angle. Likewise long period waves reaching a beach in a region of very steep offshore slopes may not undergo sufficient refraction to eliminate the effects of direction upon the breaker angle.

This condition is characterized by waves which strike the beach first at one end or the other and a breaking process which proceeds down the beach in the direction in which the waves are traveling. The effect of this obliquity is to set up current in the surf zone traveling parallel to the shore and in the same direction as the waves are traveling. For high waves of great angle this littoral drift may be as great as three or four knots and impose great difficulties upon an amphibious operation. In addition, under these conditions, an amphibious craft traversing the surf zone is subject to wave impact at an angle with the normal line of travel. This combination very readily leads to broaching in the surf and for ordinary craft broaching while on the beach. The DUKW and LVT are not critically affected when they are land-borne. Such longshore currents do, however, produce a much more hazardous landing condition than exists in their absence. The currents have a much greater velocity in certain parts of the surf zone and the operator must be constantly alert to combat their effects and avoid broaching. In order to successfully traverse the surf zone where the waves are breaking at an angle it is necessary first to estimate the direction and total distance of drift and to direct the course so that the craft always meet the breakers **normal** to their crest; that is, head on or directly astern.

E. BREAKER PERIOD AND ITS EFFECT ON LANDING CRAFT

The period of the breaker is a very important factor primarily as it frequently determines the type of breaker, the amount the wave will increase in height as it approaches breaking, the amount of refraction the wave undergoes and the velocity of the wave. These matters are described as separate factors, however, and the direct effect of period on the amphibious operation is simply a matter of the rapidity at which the craft encounters breaking waves. Short period storm waves from local sources may arrive every six to twelve seconds. The landing craft does not have an opportunity to pass the breaking point without meeting a breaking wave, and is subjected to such a continuous impact that the coxswain may lose his bearings and be unable to orient himself. Long period waves may arrive every ten to twenty seconds and on steep beaches there is an opportunity for the landing craft to pass through the breaker zone between waves.

F. EFFECT OF BOTTOM CONFIGURATION ON BREAKERS

In general, at any point on a beach where the breakers are occurring farthest from shore the breaker will be highest. This results from the fact that offshore from such a point there must be a bottom configuration tantamount to a submarine ridge. Such configuration leads to the convergence of waves upon the portion of the beach immediately to

shoreward thereof. Conversely, regions in the surf zone where the outer breakers are constantly breaking closer to shore than elsewhere will be generally regions of lower breakers due to the fact that here a condition of divergence over a small channel must exist. The presence of rip currents (seaward currents) in such channels complicates the refraction pattern in such regions and there are normally present two opposing situations, first the currents which tend to make the waves converge and the partial channel which tends to make the waves diverge. If this first condition governs, the waves may completely converge and break in the middle of the channel. They will almost invariably, however, be breakers of a spilling nature and consequently less hazardous than the waves which would be encountered on the more seaward points.

G. BREAKER HEIGHT DETERMINATION

The height of a breaker is measured vertically from the crest to the preceding trough. As the wave from deep water approaches a beach it peaks up after it feels the bottom and continues to increase in height until it breaks. This increase in height over the deep water conditions is a function of period and height of the deep water wave. This increase can be determined by tables included in H.O. Misc. No. 234, "Breakers and Surf", and may be of a factor of two or more. Thus it is never safe to estimate the height of swell offshore and assume the breaker height will be the same.

H. ESTIMATING HEIGHT OF BREAKERS

Breakers are usually larger than they appear to be from the beach. A method of estimating breaker heights visually without the use of mechanical or optical aids is described as follows: The observer on the beach adjusts his position vertically so that his line of sight corresponds with the top of a breaker and the horizon. The vertical distance from this line to the lower limit of the backwash will be the approximate height of the breaker. The lower limit of the backwash in this case being considered the lower limit of the trough between the breakers close to the beach and is progressively less accurate as distance increases. Where the breakers are far offshore, as on the flat beaches of the North Pacific Coast, there is a very noticable tendency to underestimate the breaker height. A fifteen foot breaker does not appear to be very large when it is over a mile off the beach and is viewed from the beach. Experience is necessary in estimating the height of the surf under all circumstances, but particularly on flat beaches. Due to variations of breakers, at least ten minutes is regarded as a minimum time for adequate observation of surf with longer periods of observation giving more accurate results.

I. DEPTH OF BREAKING

The depth of breaking is the still water depth at the point where the waves break. The depth of breaking on an evenly sloping beach is approximately 1.3 times the height of breaking. However, when a bar is present it may cause waves to break in water up to 1.7 times the breaker height.

J. SPEED OF BREAKERS

The speed of a breaker depends upon the depth of breaking. For a six foot breaker the depth of breaking is eight feet and it follows that this breaker advances with a speed of about ten knots. The relationship of breaker height to breaker speed of advance is shown in the following table:

BREAKER HEIGHT	SPEED OF BREAKER ADVANCE
4 Feet	8.5 Knots
6 Feet	9.8 Knots
8 Feet	11.0 Knots
10 Feet	12.2 Knots
12 Feet	13.3 Knots

K. SURF ZONE CATEGORIES

As in breaker types, the surf zone may be divided into two categories; that caused by waves from local onshore winds and that caused by swell from a distant wind area or "fetch". A combination of these may be found together, causing the surf zone to assume a mixed and irregular character.

The surf zone caused by local wind waves is characterized by short irregular crest, spilling breakers and a generally confused aspect. The waves offshore are steep with many white caps and the crests do not increase in height before they break.

The wave period is short, usually about five or six seconds. Surf zones of this category are a characteristic of the continental coasts outside the tropics and of all confined waters. It was the only surf of importance on the Normandy beachheads, since in summer swell from the open ocean does not enter the English Channel.

The surf zone caused by swell from a distant wind area is characterized by regular crests, plunging breakers and long lines of foam.

The period of the waves if from eight to fifteen seconds and their length at breaking greater than one hundred and fifty feet. The waves offshore appear low and rounded, but immediately before they break they peak up sharply, in some cases even doubling their deep-water height. In the northern hemisphere surf zones caused by swell only is a characteristic of western continental shores south of 35° north, which are exposed to swell from the prevailing northwesterly winds in the middle latitudes. North of 35° north the western coasts are exposed to both sea and swell, and a mixed surf zone is usually encountered. Surf zones caused by swell occurs on the north and east coasts of the Philippines and the east coast of Formosa during the seasons of the northeast monsoons and the typhoons. Typhoons may also give rise to surf caused by swell on the coast of China and Japan and around Western Pacific Islands.

IV. FACTORS AFFECTING SURF AND SURF ZONE

A. SANDBARS

Wherever bars are present the wave crests will peak up as the waves roll over the bar. The water depth over the bar and the wave height determine whether or not breaking takes place on or near the bar. If the water depth over the bar is more than twice the significant breaker height, nearly all waves will pass over the bar without breaking but the crests will peak up distinctly. If the depth is between one and two times the breaker height, waves will break near the bar, some on the bar itself and others on the shoreward side. With water depth less than the breaker height all waves will break on the seaward side. Frequently more than one bar exists with waves breaking and reforming, and breaking again on another bar or on the beaches. The striking pattern of these breakers in aerial photographs is a certain indication of the presence of bars. Off Vierville-Surmer, Normandy, several bars exist. Shallow bars can seriously impede landing craft (Sicily).

The importance of beach slope to surf lies in its effect on the width of the surf zone. The breaker line which represents the seaward border of the surf zone is found where the depth to the bottom equals about 1.3 times the significant breaker height. Thus, with 6-foot breakers the breaker line is located where the depth to the bottom is about 8 feet, regardless of beach slope. Off a beach with a slope of 1:10 the breaker line for six foot breakers is only about 80 feet from the shore line, whereas off a beach with a slope of 1:50 the breaker line is about 400 feet from the shore line.

B. BEACH SLOPE

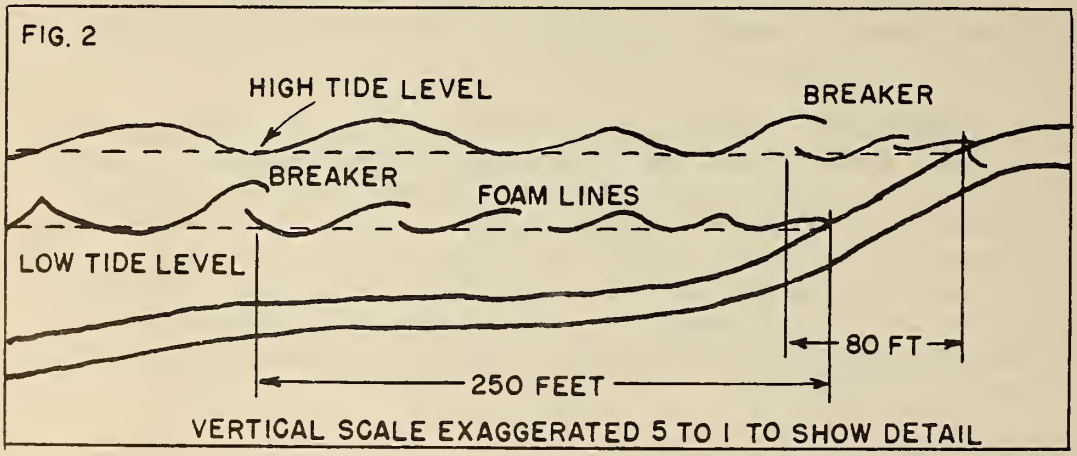
Off a very steep beach there may be no lines of foam inside the breaker line, and each wave, after breaking, rushes violently up the shore face and hits any beached craft with great force. Off a flat beach on the other hand, there will be numerous lines of advancing foam between the breaker line and the shore line, the energy of the waves will be expended during the advance through the surf zone and there will be only a gentle uprush and backrush on the beach.

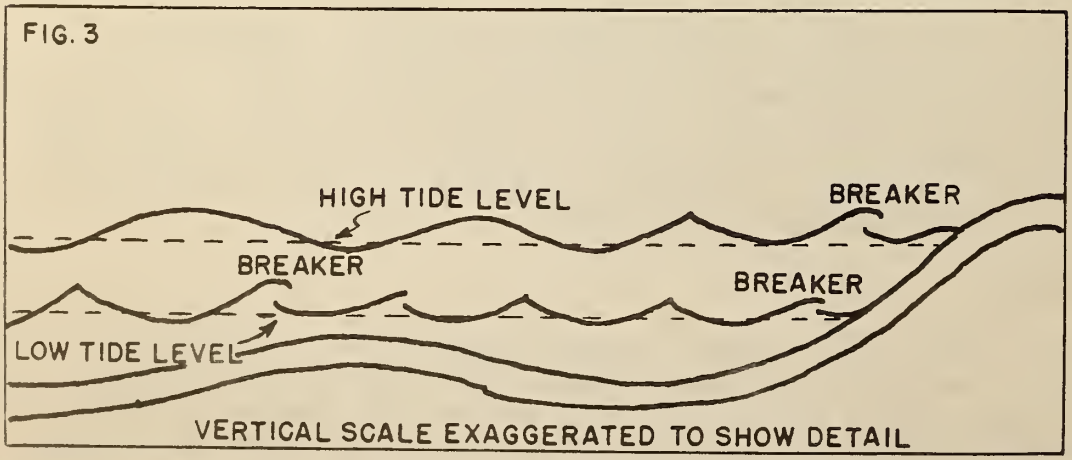
C. TIDE

The stage of the tide has little effect on the height of the breakers but can have a profound effect on the width and character of the surf zone. This is the case on all beaches with bars and on all beaches which have a steep upper slope and very gentle slope at or below

the low-water line. These effects of the tide are illustrated schematically in figures 2 and 3. Figure 2 shows a beach which at high tide has the characteristics of a steep beach with 6-foot breakers at a distance of 80 feet from the waterline, but at low tide has the characteristics of a flat beach with 6-foot breakers at a distance of 250 feet from the waterline and with several lines of foam in the surf zone. Figure 3 shows a flat beach with an off-lying shallow bar which is nearly exposed at low water. At high tide there is a single line of breakers but at low tide the waves break beyond the bar, reform and break again on the beach.

It is possible to contour a beach between high and low water lines by photographing it at different stages of the tide. The water line along the beach marks the contour corresponding to the height of the tide at the time the photograph was taken.





D. REFRACTION

The surf depends not only upon the beach slope directly off the shore line but also upon the bottom contours at great distances from the coast. As soon as a wave travels into water which is sufficiently shallow for the wave to "feel bottom" its speed decreases. Therefore, when a wave approaches a straight coast at an angle the part of the wave first reaching shallow water slows down, whereas the part which is still in deep water speeds on, with the result that the wave crest swings around and tends to become parallel to the coast line. This bending of the crests is called REFRACTION. Refraction accounts for the fact that the breakers nearly parallel the beach even when the offshore waves travel at a considerable angle with the coast line.

Refraction also occurs where waves travel over an irregular bottom. The portion of a wave over a submarine ridge is slowed down, and the portions of either side tend to swing in toward the ridge. Where the waves swing together, each crest is squeezed and the wave height is increased. Heavy surf is found wherever a submarine ridge runs out from a coast. A submarine canyon has the opposite effect. The portion of the wave over the canyon travels faster than that on either side, and tends to fan out. Where the wave fans out, the crest is stretched and the wave height is decreased. The surf is light wherever a submarine canyon runs out from the coast. This relationship observed by navigators has given rise to the expression "the point draws the waves", as they realized that the waves are frequently higher offshore of a point. Similarly seamen also have learned that the sea may be calmer at the head of a submarine canyon than in the regions on either side.

There is not much variation in wave height along the Oregon and Washington coasts from the bottom effect except in the vicinity of some of the offshore banks and at the entrances to harbors and mouths of rivers, particularly the Columbia. The California coast is extremely complex, however, and there may be large variations in wave height due to the bottom effect alone.

Refraction also causes the waves to swing in behind islands and peninsulas where they could not reach if they continued in their original direction. Therefore, the amount of protection afforded by headlands, peninsulas, island, and other obstructions depends as much upon the underwater topography as upon the shape of the coast line.

In order to predict the variation in surf along a coast line refraction diagrams must be prepared. They must be based on the most accurate charts of the region and must be constructed for waves of different directions and periods. Since the relation between wave speed

and depth is known, it is possible to plot the advance of a wave during given time intervals. Such diagrams show the pattern of the wave crests as they approach the shore and reveal the regions where the crests are "squeezed" or "stretched". From this pattern it is possible to calculate the variations in breaker heights along the coast.

E. CHANGES IN BOTTOM CONFIGURATION

Various types of bars are found off shorelines. The type of bar related to coral islands will not be considered here since this type is now of less significance to landing operations and also has been well described elsewhere. Of the submerged sand bars, three common types exist. The first type is found off many large rivers and is often associated with deltas. The multiple bars of this type cover a large area and have a wide range in depth, many of them extending above sea level. Charts of these bars are accurate only at the time they are made. The bars change tremendously in size and position at times of floods and of high surf. The general effect of floods is to decrease their depth and to increase their area whereas high surf has the opposite effect.

The second type of bar has roughly a crescent shape and extends convexly out from the mouths of rivers and from the bottleneck entrance of bays. Well known examples are found off San Francisco Bay, the Columbia River, and Humboldt Bay. The bars off these areas are too deep to interfere with landing craft, but many such bars off smaller entrances are sufficiently shallow to offer serious hindrance to landings. In landing operations it may be of advantage to use beaches in estuaries and bays where the surf is low, but access to these areas may be difficult because of high breakers on the deep crescentic bar lying off the estuary or bay. Ordinarily there is at least one channel through the bar. While the position of the channel may shift it is likely to remain at the same general location and can be spotted from the air. This type of bar probably deepens during periods of high surf, although no direct evidence is available.

The third type comprises bars which parallel the majority of sand beaches. In some places they occur only during the season of largest waves, but elsewhere they persist throughout the year. Longitudinally the bars may be continuous for miles, but are likely to be discontinuous, being developed off some portions of a beach and not off others. The breaks in the bars can be detected from the air from the breaker pattern. In some very sandy areas a series of bars extends for miles out to sea and the outer ones attain depths far too great to interfere with amphibious operations. However, the typical depth of the longshore bars ranges from about 3 to 15 feet below mean low water.

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These offshore bars, particularly the shallower ones, are a serious menace to landings. Landing craft are often "hung" on the crest of the bars and a considerable time interval may elapse before they are able to cross. If troops debark while the craft is hung on the bar, they must cross a channel between the bar and the beach. This channel may be too deep to cross by wading and may have strong currents. Where large waves are approaching the crest diagonally these currents are especially prominent. In some cases where a landing craft is hung on the bar the current will cause it to broach.

Bars are greatly modified in depth and distance from shore by high surf. From available data there appears to be a rough relationship between bar depth and the maximum breaker height during the preceding one or two weeks. It seems likely that the bar would attain a depth slightly less than the depth of breaking at low tide, if the breakers remained constant in height for a sufficient period. However, the large waves do not ordinarily last long enough to bring about this adjustment. Daily measurements of variation of bar depth with wave height were made along a California pier. It was found that high breakers caused rapid deepening of the bar. Also the high breakers often decreased the size of the bars or even eliminated them, but in some other cases high breakers caused the formation of a bar by cutting inside the most violent breaker action and leaving a somewhat higher zone outside. With low breakers the bars tend to grow shallower and to move shoreward. The trough inside the bar either keeps pace or fills more rapidly until the bar disappears.

There is reason to believe that the troughs inside the bars may be filled quite rapidly if the usual longshore current is reversed. Since this current in areas lacking strong longshore currents is determined largely by the direction of the approach of the swell, change in the current direction may be detected by aerial photographs. In the areas with longshore tidal currents the bars are likely to exist at all seasons.

The bars along the California coast show a marked seasonal effect. They are practically non-existent at the end of the summer period of small swell. In general, in the fall they form during or shortly after the first period of high breakers. During the winter the bars deepen and as the breakers decrease during the spring the bars move shoreward and decrease in depth, being largely eliminated during the light surf period of the summer. While only fragmentary evidence is available from other areas it seems very probable that the same sequence develope in relation to the stormy season.

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V. SHORE AND TIDAL DESCRIPTION

A. OFFSHORE CURRENTS

Both offshore and inshore currents are of importance in amphibious operations. Offshore currents -- tidal or nontidal -- are found outside the surf zone. Tidal currents predominate around the entrances to bays and sounds and in channels between islands, or between an island and the mainland. They are oscillatory, that is, they change their direction every six or 12 hours, depending upon whether there is a semidiurnal or a diurnal tide, and in narrow sounds they may reach velocities of several knots. On the surface tidal currents may be visible as "tide rips", areas of broken water and white caps. The tidal currents are predictable, if sufficient observations have been made, because they repeat themselves as regularly as the tides to which they are related.

Nontidal currents are related to the distribution of density in the ocean and the effect of the winds. Examples are the Gulf stream off the American east coast and the Kuroshio which flows along the east coast of Formosa, west of the Ryukyus, and along the southeast coast of Japan to latitude 35° N. In the Kuroshio velocities up to three knots have been observed. Currents of this type are constant for long periods, although they may vary in velocity and direction at different seasons of the year.

B. SHORE CURRENTS

Shore currents are set up within the surf zone by the breaking waves. Longshore or littoral currents flow parallel to the shoreline inside the breakers and are most commonly found along straight beaches. They are caused by waves breaking at an angle with the beach. Their velocity increases with increasing breaker height, with increasing angle of the breaker with the beach, and with steeper beach slopes. (Note: A breaker arriving parallel to the beach has an angle of 0° to the beach.) It decreases with increasing wave period. With 8-foot breakers sustained velocities of three knots have been measured. The longshore currents are predictable but the accuracy of the forecast will depend upon the accuracy of the wave forecast on which it is based. In areas where longshore currents are common, sand bars are usually present.

C. RIP CURRENTS

Rip currents flow out from shore through the breaker line in narrow rips, and are found on almost all open coasts. They consist of three parts, the "feeder currents" which flow parallel to shore inside

the breakers, the "neck" where the feeder currents converge and flow through the breakers in a narrow band or "rip" and the "head" where the current widens and slackens outside the breaker line. An observer can distinguish the neck of a rip current as a stretch of unbroken water in the breaker line. The outer line of the current in the head is usually marked by patches of foam and broken water similar to tide rips, and the head itself is usually discolored by the silt in suspension.

Rip currents are caused by the waves piling water against the coast. This water flows along shore until it is deflected seaward by bottom irregularities, or until it meets another current and flows out through the breakers. Once feeder and rip currents have formed, they cut troughs in the sand and remain fairly constant in position until the wave conditions change. Common locations are at the heads of indentations in the coast. When waves break at an angle on an irregular coast, the rips will be found opposite small headlands which deflect the currents seaward. In this case there is only one feeder current. The velocity of the feeder and rip currents, up to two knots, and the troughs they cut in the sand may both form hazards for landing craft.

Any time that waves break at an angle with the beach, currents will be formed in the surf zone. If the beach is straight they will flow along the beach as longshore currents, and if the beach is irregular they will flow along the shore for a short distance and then flow out to sea as rips.

VI. LANDING CRAFT CASUALTIES

A. TYPES AND CAUSES OF LANDING CRAFT CASUALTIES

A casualty is defined as any mishap by which a craft is put out of operation temporarily or permanently. Casualties due to beach and surf features can be summarized as follows:

1. SWAMPING by breakers when approaching or retracting.

2. HANGING up on a bar.

3. BROACHING on a bar or on the beach.

The surf and beach conditions to which such casualties may be ascribed, even with expert boat handling are:

1. The character of breakers, their height, type, and period.

2. Presence of bars.

3. The beach slope which, with a given breaker height, determines the width of the surf zone.

4. Longshore currents.

B. SWAMPING OF LANDING CRAFT

Swamping is rarely caused by surf conditions alone. Even with 10 to 12-foot breakers an experienced coxswain can bring his craft safely through the breaker line, but he has to use all his skill because these breakers travel with a greater speed than his craft. The speed of a 10-foot breaker is 12 knots and the top speed of an LCVP or an LCM is about 10 knots. If a craft is overtaken by a plunging breaker it will be in great danger of being swamped. If it is overtaken by a spilling breaker it may "surf board", that is, it may be carried along by the foaming water, get out of control and collide with another craft. If there is a narrow surf zone the coxswain may not regain control before the craft hits the beach and broaches.

During the retraction there is a greater danger of the craft being swamped, particularly if it ships water from several successive breakers. Retraction through plunging breakers is more difficult than through spilling breakers, but that is partly compensated for by the

longer periods of plunging breakers. An experienced coxswain can generally retract an LCM safely through about 7-foot breakers.

Most casualties occur because craft get hung on a bar or broach on a bar or on a beach. With the same depth of water over a bar the risk of a craft getting hung is greater when the breakers are low, because higher surf may assist the craft in clearing the shallow water.

C. BROACHING OF LANDING CRAFT

Broaching frequently occurs when a powerful crest hits a beached craft. The power of the broken crest hitting the beach depends upon the height of the breakers and their distance from shore. On a steep beach the breaking takes place at a short distance from the waterline and is followed by a violent uprush on the beach. The danger of broaching is great unless the craft can be held firmly against the beach. It is much more difficult to prevent the broaching of the single screwed LCVP than the twin screwed LCM. With a wide surf zone, on the other hand, the broken crests expend their energy as they advance through shallow water, the uprush on the beach is gentle and the risk of broaching is greatly reduced. Where the width of the surf zone changes with the stage of the tide the difficulties to be expected in landing operations will also depend upon the tide. Longshore currents are a frequent cause of broaching.

VII. SURF IN AMPHIBIOUS PLANNING

In order to properly plan and carry out combat amphibious landings, it is necessary to have intelligence information and correct evaluation. The primary aim of the studies made at this time is to determine certain oceanographic factors which affect an amphibious operation.

A. PLANNING FOR WAVE, BEACH, AND SURF CONDITIONS

The following sections deal with methods of obtaining pertinent surf information desirable in planning a landing. Some uses of the information obtained are:

1. Selection of Beaches

Within limits set by strategic and tactical considerations, landing areas should be selected with reference to surf and beach conditions under exposure to different wave conditions. After the hydrography of each area has been obtained, wave refraction diagrams should be drawn to show the variations in surf conditions along the beach for wave periods and deep-water directions over the entire possible range. Alternative landing plans for each landing area will be desirable if the analysis shows markedly different surf conditions under exposure to waves of different possible directions and periods.

2. Selection of Ships, Craft, and Vehicles

The selection of ships and landing craft with relation to anticipated surf conditions should be completed during the early planning of an operation. It is possible to plan for surf at this stage only on a statistical basis, but the probability of light or heavy surf action at the time and place of the landing should not be ignored. On shorelines noted for severe surf, there are some days of relative calm, and on shores where the surf is normally light, there are usually some days of heavy surf, but the assumption of abnormal conditions is unwise.

3. Training and Briefing of Personnel (Beach Masters, Coxswains, Salvage Boats, etc.)

a. Selection of Training Areas

At least a portion of the personnel involved should be exposed to surf and beach conditions similar to those at the selected landing areas.

b. Briefing of Landing Force Personnel

A combination of aerial photographs and sketches should be prepared in advance from which can be selected, just prior to the assault, those conforming most closely to the expected landing conditions. Transparent overlays might carry instructions for the different functions and levels of command. Surf photographs from the shore, from the sea and from the air should be available for a similar beach under a variety of surf conditions and a selection made to represent the expected conditions. Briefing should cover the following items:

(1) Size and type of breakers.

(2) Type of surf area.

(3) Direction of longshore current.

(4) Tide state (for example, the cargo state should be at half tide on the flood if possible).

B. PLANNING STAGE

During the planning of an operation the seasonal character of the surf in the area can be examined. With climatological data and historical weather maps at his disposal, an aerologist trained in sea and swell forecasting can determine the character and direction of sea and swell advancing toward the coast. He can provide information as to the season in which unfavorable surf conditions are least probable, whether landings on alternate beaches should be considered, and he can indicate the weather situation which will favor one or the other of such beaches.

In order to examine the actual character of surf, he requires detailed information regarding the shape of the coast line, the slope of the beach directly above or below the low-waterline, and the offshore bottom topography. Knowledge of the bottom topography is necessary for the construction of refraction diagrams which will show to what extent any given locality is protected from, or exposed to, sea and swell from various directions; refraction diagrams are also indispensable for forecasting for a specific time.

The width and character of the surf zone depends upon the beach profile directly off the shoreline, including bars and other obstacles to landing operations. Navigation charts seldom show these details and all possible means of determining the beach profile should therefore be used during the planning stage. Special photographic techniques are

necessary, and any program of beach studies using these methods should be initiated as early in the planning stage as possible. The trained aerologist is familiar with these methods based on aerial photographs of wave characteristics, and when these can be used he should cooperate with the photo interpreter to insure the best possible results.

The offshore bottom topography from which the refraction diagram is drawn is usually permanent, but the beach near shore will change with waves and tides. The effect of wave action on the beach features in turn depends upon the beach material, and the latter is also important to traffic across the beach. Some information about beach material can be obtained from repeated photographic surveys, particularly if a geologist can assist in the examination of the photograph.

Accurate knowledge of the tides is needed. This is particularly true where the tide range is large and where the beach has an uneven profile with offshore bars, which are exposed or barely covered by water at low tide. Tide tables are available for the Pacific areas, but for the China coast the information is incomplete and should be supplemented by observations in order to make adequate predictions possible. Table 1 on page VII-4 lists the different features which can be examined during the planning stage and by whom the information can be best found.

The aerologist should be required to initiate forecasts and to have them verified by aerial reconnaissance at least one month before D-Day. This will permit him to make corrections for local variations so that his forecasts for D-Day are based on first hand knowledge of local conditions.

C. INFORMATION FOR D-DAY

The surf conditions on a beach of known exposure and profile can be forecast about 24 hours in advance by aerologists who have received training in this particular form of forecasting. The forecast features comprise:

1. The width of the surf zone.
2. The significant breaker height.
3. The depth of breaking.
4. The angle of the breakers to the beach.
5. The wave length directly outside the breaker line.
6. The longshore currents.
7. Period of breakers.

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TABLE 1

PRELIMINARY DATA REQUIRED DURING PLANNING STAGE

FEATURES DETERMINED	PERSONNEL RESPONSIBLE	METHODS AND SOURCES
1. Prevailing Winds	Aerologist*	Wind roses from climatological data.
2. Prevailing sea and swell	Aerologist*	Swell roses from climatological data.
3. Beach slope	Photo Interpreter#	Interpretation of aerial photos.
	Intelligence	Use of H.O. Charts and other sources.
	Aerologist*	Soundings
4. Beach irregularities	Photo Interpreter#	Interpretation of aerial photos.
	Intelligence	Use of H.O. Charts and other sources
	Aerologist*	Soundings.
5. Refraction diagrams	Aerologist* assisted by Hydrographer	Prepared from latest UDT survey or other available hydrographic data.
6. Prevailing surf	Aerologist*	Prevailing swell; refraction diagrams.
7. Currents	Intelligence	Research from charts and publications.
	Aerologist*	Research from charts and publications.
	Hydrographer	Research from charts and publications.
8. Tides	Intelligence	Interpretation from prepared tables.
	Aerologist*	Interpretation from prepared tables.
	Hydrographer	Interpretation from prepared tables.
9. Beach materials	Photo Interpreter#	Interpretation of aerial photos.
	Intelligence	Data compiled from publications.

NOTE: *Aerologist trained in "Surf and Swell Forecasting".
#Specially trained in depth determination from aerial photographs.

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TABLE 2

DATA AVAILABLE FOR D-DAY

FEATURES DETERMINED	PERSONNEL AVAILABLE	METHODS
1. Surf and Swell conditions	Aerologist	Surf and swell forecasting procedures.
	Airborne observer	Surf observers make reconnaissance flights.
2. Tides	Aerologist, Hydrographer, and Intelligence Officer	Calculations from H.O. reports, and UDT information.
	Airborne observer	Verification of stage of tide against prediction by flying over beach.
3. Currents	Aerologist and Intelligence Officer	Forecasting longshore current. Current charts.
	Airborne observer	Verification by aerial flight over beach.
4. Depth of water and beach slope	Photo Interpreter Aerologist and Airborne observer.	Wave velocity method Wave length method
	UDT	Soundings in area.
	Hydrographer	Beach study.
5. Beach features (bars, troughs).	Photo Interpreter	Photographic interpretation.
	Airborne observer	Note changes due to waves and surf.
	UDT	Soundings.
6. State of the sea	Aerologist	Wave and swell forecasting.

In order to forecast the surf condition on any beach the deepwater waves (sea or swell) must be known. These can be determined in one of two ways: from weather maps, or from direct measurements offshore. Direct measurements are required if adequate weather maps are not available and are always desirable in order to check results from weather maps. Table 2 on page VII-5 lists data required for D-Day.

From a knowledge of the deepwater waves and the bottom topography surf conditions can be predicted. In the case of alternate beaches, forecasts will indicate where surf conditions are most favorable.

At this point it is considered important to bring to the attention of amphibious planners the factors influencing the accuracy of surf forecasting. A large portion of the information needed for a surf forecast is usually derived from a previously prepared weather analysis. The purpose of the analysis is to determine which areas of open ocean may be considered as wave generating areas. Presuming that correct and adequate information is available for the weather analysis, it may be assumed that if complete and adequate hydrographic information is available the resultant surf forecast will be accurate. An experienced surf forecaster considers a forecast accurately verified if the observed breakers are within the following limits:

Forecast height	Tolerance allowed for verification
0 - 5 Feet	Plus or minus $\frac{1}{2}$ foot
5 - 10 Feet	Plus or minus 1 foot
More than 10 Feet	Plus or minus 2 feet

It should be borne in mind, however, that a scarcity of weather reports, imperfect communication facilities, or erroneous hydrographic data will seriously limit the ability of the forecaster to prepare a correct surf forecast.

Surf intelligence does not end with D-Day. In planning the landing of supplies and replacements a knowledge of surf conditions can be very helpful. During the supply phase at Omaha Beach, Normandy, forecasts of the ending of heavy surf conditions were found particularly useful in scheduling the resumption of unloading operations. After the objective is secured a knowledge of beach and surf conditions is valuable in choosing and developing harbors and anchorages.

D. PERCENTAGE OF CASUALTIES IN LANDINGS WITH LCVP AND LCM

In order to determine how many casualties may be expected under various surf conditions, about 12,000 individual landings of LCVP and LCM

were observed at the Amphibious Training Base at Coronado, during the later stages of World War II.

The number and causes of the casualties were observed by experienced coxswains capable of recognizing mishaps caused by either poor seamanship or the surf. In order to bring out the effect of surf only, all casualties were eliminated which could be ascribed to inexperience.

Most landings were made with breakers less than 6 feet high and under these conditions the BREAKER HEIGHT and the BEACH SLOPE were the two most important features to which surf casualties could be related.

The Amphibious Base at Coronado has a beach with a steep upper slope above the low waterline and a flat slope with bars below the low waterline. At high tide the Coronado beach has, therefore, the character of a steep beach, whereas at low tide it has the character of a flat beach with some off-lying bars.

The results of the studies are shown in table 3 below and figures 4 and 5, on pages VII-8 and VII-9. The casualties are expressed by the percentage of craft that were put out of operation during an operation in which 25 or more single landings were made. The relations between casualties, breaker heights and beach slopes are represented by bands. These show the range in significant breaker height at which any given percent of casualties may be expected.

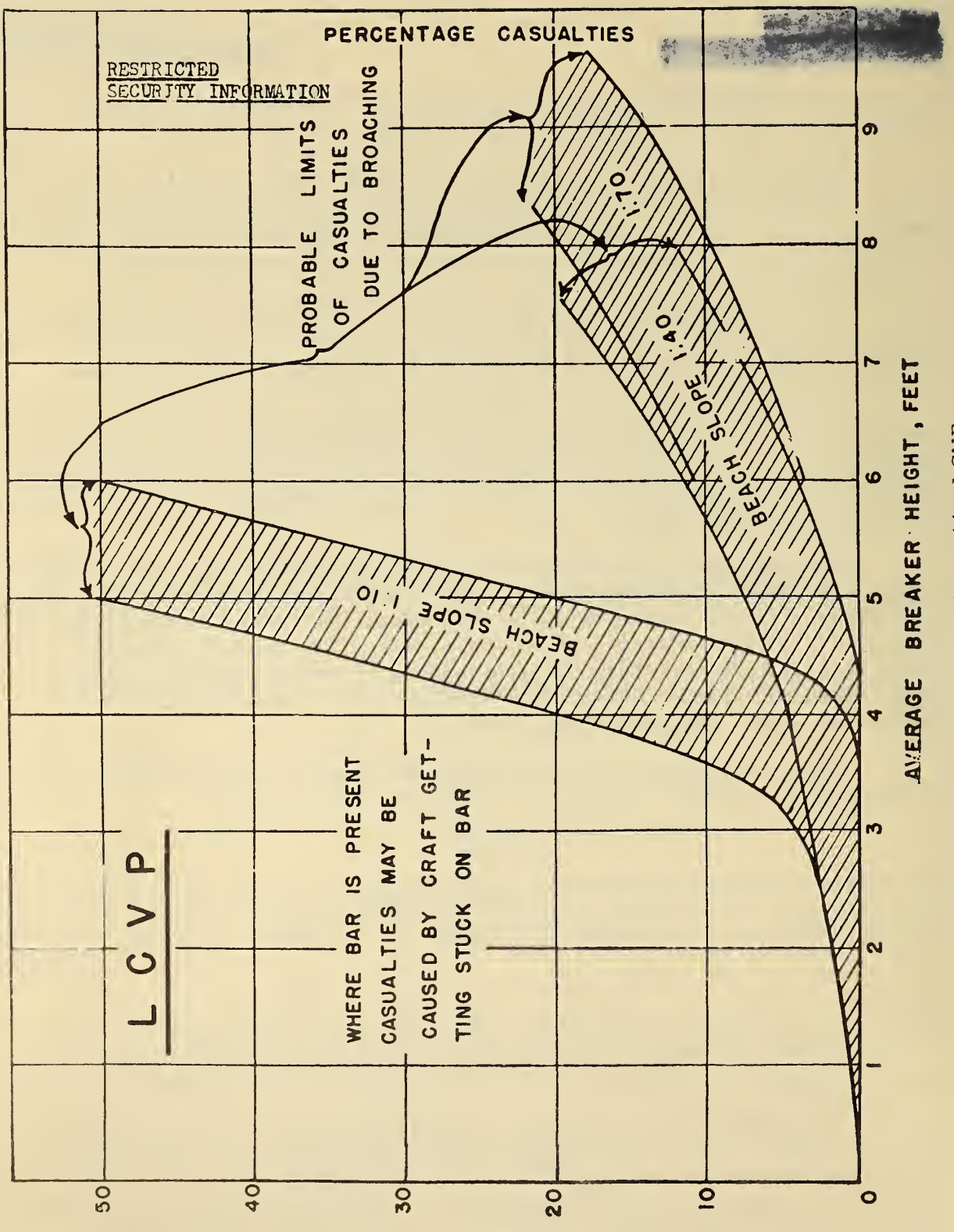
From the figures it is found that the breaker heights which cause 20 percent casualties on beaches of different slopes are:

TABLE 3

	BEACH SLOPES			
TYPE OF CRAFT	1:10	1:25	1:40	1:70
LCVP	4' - 5'	6' - 7'	7.5' - 9'	8' - 10'
LCM	8' - 10'	8' - 10'	8' - 10'	8' - 10'

(From "Surf Manual for Amphibious Operations", COMINCH Pub. P-9, 10-8-45)

Corresponding values for other percentages can be interpolated from the graphs. For the LCVP there is a striking effect of the beach slope, but for the LCM the beach slope is unimportant as long as the steepness is less than 1:10. Experience on Iwo Jima shows it is probable that on steeper beaches many LCM would also broach with breakers even lower than 5 or 6 feet.



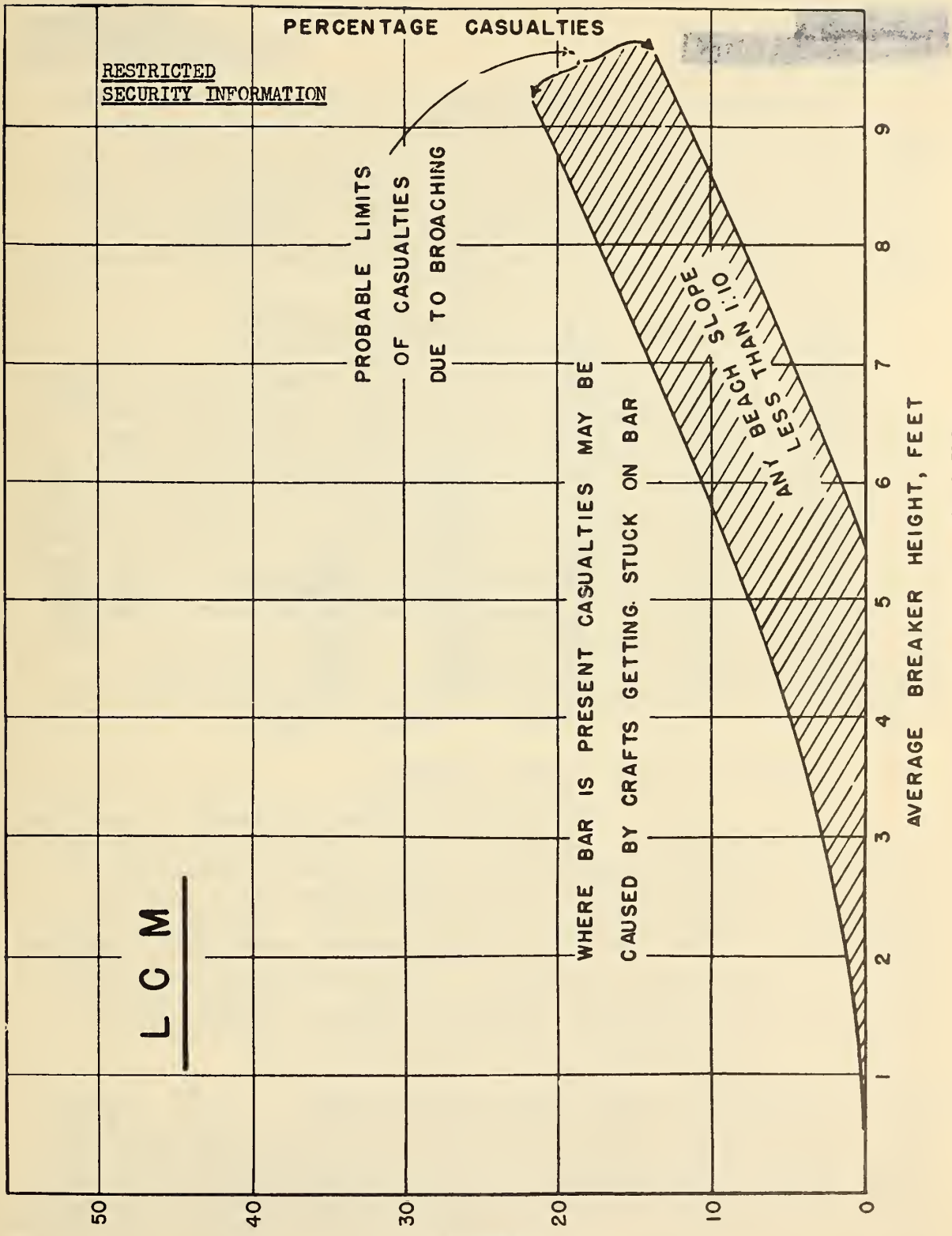
Graph of casualties LCVP

FIGURE 4

(From "Surf Manual for Amphibious Operations", COMINCH Pub. P-9, 8 Oct 1945)

[redacted]

[redacted]



Graph of casualties LCM.

FIGURE 5

(From "Surf Manual for Amphibious Operations", COMINCH Pub. P-9, 8 Oct 1945)

[redacted]

The information in figures 4 and 5 is derived from observations of landings with unloaded craft which spent a very short time on the beach. It is believed that in the absence of bars nearly similar results will be obtained if the craft carry troops and stay on the beach for a few minutes only, but that the percentage of casualties will be considerably greater if the craft carry supplies. With loaded craft and in the presence of shallow bars many more casualties can be expected because of craft getting hung on the bar.

E. LIMITING BREAKER HEIGHTS FOR TRAINING OPERATIONS

The question may arise in the planning of amphibious training operations as to what heights of breakers may be considered the maximum under which an operation may be safely conducted. Figure 6 on page VII-11 gives a graphic indication of the maximum heights which will normally limit training operations. The data utilized in constructing this graph have been obtained both from studies of the characteristics of landing craft by research scientists and from the opinions of officers familiar with the characteristics of landing craft in surf through years of experience. IT MUST BE UNDERSTOOD THAT THESE LIMITS ARE INFLUENCED BY OTHER CONDITIONS SUCH AS LITTORAL CURRENTS, EXPERIENCE OF COXSWAINS, ETC. WHICH WOULD VARY THEIR EFFECTIVENESS IN SPECIAL CASES. THE VALUES PRESENTED HERE SHOULD BE CONSIDERED ONLY AS A GUIDE FOR PLANNING PURPOSES, AS ANY ACTUAL DECISION CONCERNING AN INDIVIDUAL OPERATION AT A CERTAIN BEACH MUST LIE WITH THE COMMANDER CONCERNED.

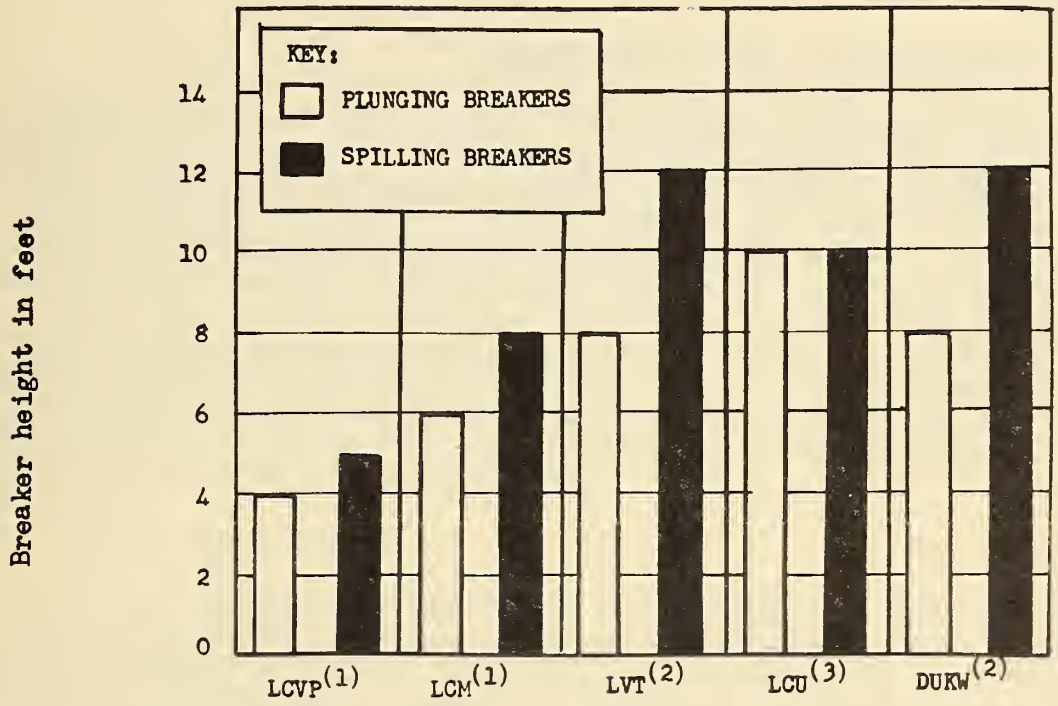
F. INFLUENCE OF WINDS ON BOAT OPERATIONS

Winds, of course, give rise to all waves with which an amphibious operation is concerned. In addition to this, wind affects the breaker type as described more fully in other sections of this publication. It also affects the speed and control of landing craft in the surf zone. The effect of winds in modifying the breaker type is frequently advantageous, however, landings have been made through the surf during a thirty knot onshore wind without difficulty. An offshore wind frequently results in a violently plunging surf and decreases visibility by forming the dense streams of spray called "Horses' Manes". This condition sometimes decreases visibility to a great extent.

G. INFLUENCE OF VISIBILITY ON BOAT OPERATIONS

Fog and rain have little influence on an amphibious operation unless the surf zone is obscured. It is extremely dangerous to put into a beach when the surf characteristics cannot be estimated. There is never any justification in assuming that the breaker condition will remain constant for even a short period of time and it is dangerous to assume that

FIGURE 6



NORMAL PEACETIME TRAINING LIMITS FOR OPERATION OF LANDING CRAFT IN SURF

(1) Data supplied by OIC Landing Craft Control School, Naval Amphibious Base, Coronado, California.

(2) Data from University of California studies of Landing Craft performance in surf.

(3) Data supplied by Commander LCU Division 32, Naval Amphibious Base, Coronado, California.

CAUTION: IT MUST BE UNDERSTOOD THAT THESE LIMITS ARE INFLUENCED BY OTHER CONDITIONS SUCH AS LITTORAL CURRENTS, EXPERIENCE OF COXSWAINS, ETC. WHICH WOULD VARY THEIR EFFECTIVENESS IN SPECIAL CASES. THE VALUES PRESENTED HERE SHOULD BE CONSIDERED ONLY AS A GUIDE FOR PLANNING PURPOSES, AS ANY ACTUAL DECISION CONCERNING AN INDIVIDUAL OPERATION AT A CERTAIN BEACH MUST LIE WITH THE COMMANDER CONCERNED.

light surf still exists after fog or rain has obscured it. The energy front of a system of waves arrives on a beach quite suddenly and the wave height can increase from very low heights to an intense surf in less than one hour.

H. SPECIAL USES OF DUKW IN SURF ZONE

The principal use of the DUKW is in the surf zone. In University of California experiments with landing craft, it was the only craft which could go repeatedly in and out through high surf from beach to deep water taking measurements while so doing. It is this characteristic of DUKW that permits surveys to be made and work to be performed of a type that was impossible prior to the development of DUKW. DUKW have been used by wave project personnel to traverse the surf zone of most of the important beaches of the Pacific Coast of the United States. These uses have been (1) to take soundings and make hydrographic profiles of surf zones during varied surf conditions, (2) to take instruments out through the surf, and (3) to lay submarine cable in the surf zone.

VIII. CONSIDERATION OF BEACH FACTORS

A. BEACH TYPES

The beach type is actually the long term result of the type of waves to which it is subjected and the supply and type of sediment available. These processes, which may involve a change of beach type, normally take place at a minute rate, except where altered by adjacent jetty construction, dredging or other human intervention. These long term changes do not enter into this discussion. Certain seasonal changes will take place which will certainly affect the operation of amphibious craft, but these are difficult to forecast.

For the purpose of this discussion the gradient of beaches will be defined as the overall slope of the bottom from the high water mark to the seaward limit of the slope upon which the maximum breakers occur. Thus beaches in certain areas may be measured only to 10 to 12 feet of water and for others to 50 to 60 feet.

1. Steep Beaches

Gradients: Steep beaches have gradients of more than 1:15 (7%). During normal conditions only one wave exists in the surf zone of steep beaches at any one time. That is, a wave breaks, the swash runs up the beach face and backrush reaches its lower limit before another breaker occurs. Steep beaches normally have plunging breakers, but if they are very steep (1:4 to 1:7; 25% to 14%) they sometimes are so balanced that the breakers are of an unusual type. In this case the backrush occurs in such resonance with the incoming breaker that this water flowing down the beach fills the curling wave form with water and the breaker, instead of plunging, "rolls over" without impact. This type of breaking apparently leads to a much more effective transformation of the breaker energy into translation and the swash flows up the beach with unusual velocity and reaches a height on the beach face much greater than the height of the waves. All phases of this resonant condition have been observed. Often the period of waves and of the swash are exactly equal and every wave breaks in this fashion. Sometimes every second wave is of this type and the other plunges with great violence. As is usual for all beaches, advantage can be taken of any resonant or cyclic condition to enable an operator to make his sortie at the most advantageous time. Spilling breakers are seldom if ever seen on a steep beach. The breaker described above is not as hazardous to landing operations as the plunging breaker.

Profiles and Profile Changes: Steep beaches tend to become steeper during a period of calm seas. The summer berm advances outward and underwater berms and bars tend to disappear. The beach face may become very steep. A beach face of 1:3 or 35% has existed at Carmel River Bight during summer conditions. They tend to become flatter in profile under the influence of high seas and seas at an angle and to form a bar or berm offshore at the breaking point. This will be a berm for very steep beaches and a bar for moderately steep beaches.

Materials: Generally steep beaches are composed of course sand particles, pea gravel or gravel.

Currents: When waves break at an angle on such beaches the speed of the currents will be high. They will exist throughout the surf zone and for some distance to seaward.

2. Beaches of Moderate Gradient

Gradients: Beaches with slopes of 1:15 to 1:30 (7% to 3%) may be considered beaches with moderate gradient.

Breaker Types: Plunging breakers are less common on such beaches and spilling breakers often occur. The probabilities of each depend upon the irregularity of the beach and type of waves which exist. This has already been discussed at some length. If a bar exists, plunging breakers may occur at low tide and become spilling at high tide. High, long period swell will usually plunge at both high and low tide. The rate at which the instability is reached is an important factor in determining the breaker type. When spilling occurs on the bar the wave will frequently reform and plunge on the beach face.

Profile and Profile Changes: Beaches of moderate gradient will usually have an offshore bar at all seasons of the year, unless they are in partly protected bights or bays. This bar becomes more pronounced when high waves exist and the beach face becomes flatter. During a period of low waves the beach face becomes steeper and the bar tends to disappear or become discontinuous. Beaches of these slopes rarely have more than one bar.

Materials: These beaches are mostly composed of moderately fine sand. They may have a gravel berm at extreme high water.

Currents: When a bar exists, currents are always present in the channel to shoreward of the bar. When the waves arrive parallel to the beach these currents will be of low velocity but when the breakers

are at an angle they may reach a velocity of four knots. This flow of water normally follows the channel for some distance and then flows out over the bar at various low points 400 to 5000 feet apart. These partial channels are called rips and currents flowing to sea may be very strong. If the beach face is steep, strong currents will also exist in the inner surf zone but if it is a moderate slope they will be weak.

3. Beaches of Gentle, Mild, and Flat Gradients

Gradients: Beaches with slopes of 1:30 to 1:300 (3% to 0.3%) may be considered as beaches of gentle, mild, and flat gradients.

Breaker Types: Plunging breakers are less common on these beaches and spilling breakers are the general rule. When plunging breakers are observed they usually result from a temporary steep section of the profile. Breakers which peak up almost to a position of instability for a considerable length of time are very likely to spill because of their susceptibility to disturbing factors. These beaches frequently have several bars and it has often been noted that when a combination of long period swell and short period wind waves exist a certain amount of spilling will take place on the outer bar. This spilling may result in the obliteration of the wind waves and the dominant swell may reform in the channel behind the bar and plunge on one of the subsequent bars or upon the beach face. It has, of course, lost energy in the spilling process and will not be as high as it would have been had it broken in a plunging manner previously. The increased hazard incident to plunging breakers may result in an impassable surf on one of the inner bars even though the spilling surf is quite moderate on the outer bars.

Profile and Profile Changes: Beaches of flat gradient will usually have several offshore bars at all seasons of the year unless they are partly protected. On the northern Oregon and Washington coast these beaches have three or four bars during summer conditions but may be in some way related to the greater range of tide in the regions of these beaches. That is, the tide range is comparable to the normal breaker height. Since the water level remains for a longer time at high water and at low water than it does at intermediate points there is apparently a process which attempts to set up an equilibrium of the beach at each of these stages. This coupled with the fact that these beaches are subject to waves from two directions and of two general types may be responsible for the appearance of three bars, each bar and the beach face, representing a partial adjustment to a combination of tide stage and wave characteristic. This is partly confirmed by the extended period of heavy western swell. The beach face on such beaches is always suitable for amphibious operation except at extreme high tides, during heavy weather when the beach may be eroding at certain points, and is thus impassable to travel along the beach face by tracked vehicles.

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Materials: These beaches are composed of fine sand. A pea gravel or gravel beach face is occasionally encountered at the mouths of small creeks.

Currents: In the channels between the bars, currents may be very strong. This is especially the case when waves arrive at an angle. There is very little current at the beach face under any circumstances. The flow of water which is built up is between the bars. The channels throughout the different bars may not be contiguous. In fact, where a channel occurs through the inner bar the next bar to seaward is likely to be more shoaling at this point than elsewhere.

B. THE EFFECT OF EXPOSURE ON BEACH TYPE

In general, beaches which are subjected to waves from a variety of directions and of a variety of periods and heights are of a much more complex nature than the beaches which are affected by more limited conditions. The simplest case is that of a beach in the head of a bay or bight where the only waves reaching the beach are those which have come through the entrance and refracted and diffracted. This results in the screening out of a great number of different period waves and thus the beach is affected by certain limited types of waves only. Beaches which are so located are adjusted in such a manner that these waves arrive parallel to the beach, unless disturbed by current caused by freshets or tidal fluctuations. The adjustment results from the fact that the waves, if originally at an angle to the beach, produce a transport of the beach material in such a direction and manner so as to bring about this balance in profile. After this balance has been obtained the waves striking the beach parallel cause a general rise in water level within the surf zone. The variation of height of any breaker throughout the line of the beach is gradual and there is no direct compulsion for this increased head of water to escape in any particular manner. Thus small irregularities in the beach set up a series of partial channels throughout the surf where this transported water escapes. On beaches where conditions are very constant these cusp-like channels are unusually evenly spaced and, on various beaches, may vary in length along the beach from 20 to 500 feet or more. These cusps or undulations of the beach may cause shells and other materials to be deposited on the crest and these may interfere with the activities of DUKW both in landing and traveling along the beach. A landing point always should be selected so that the DUKW lands in the trough of these cusps rather than upon the crest. Broaching is much less of a hazard in the trough.

Beaches in large wide open bays or extremely long beaches which are subjected to waves from a constant angle frequently do not set up

this balanced condition mentioned above. This results from the fact that the points or headlands confining the beach are so limited in seaward extent that regardless of the transport of materials in the direction in which the waves are traveling the transport merely continues indefinitely without effectively changing the trend of the beach. This condition is noted through almost all the beaches immediately to the south of Point Conception. Such beaches possess relatively simple profile since forces acting upon them are of a nearly constant direction.

Beaches which are affected by the waves coming from many directions and waves of varying types are usually of a complex profile. They are affected by currents which change in direction from day to day and their profile is likely to be greatly different at closely adjacent points. They have irregular discontinuous bars of varying number, flat and steep sections and channels or rips throughout the surf zone at irregular intervals or 300 to 5000 feet. This condition is well exemplified at a number of points along the Pacific Coast where a continuous beach curves farther and farther to seaward at the southern extremity. Thus the beach from Pismo to the mouth of the Santa Maria River is, at Pismo, affected by waves primarily from one direction. The beach profile here is smooth and consistent. Between Pismo and the Santa Maria River the beach curves gradually to seaward and is subjected more and more to waves at a variety of angles. The profile becomes more and more irregular until at Santa Maria River, the beach is of a completely disordered type as described above. In general, therefore, if any part of the beach has some protection so that waves from one direction are eliminated, the profile and beach type will be more regular than it is elsewhere. This protection may not necessarily be a headland, island or jetty. For example on Clatsop Spit near the mouth of the Columbia River, part of the beach is protected from Northwest seas during the ebb tide from the river, and the beach is somewhat more regular in profile than it is farther to the south.

C. THE SEASONAL CHANGE OF BEACH TYPE

During extended periods of low waves, beaches may build high berms on the foreshore with very steep profiles of the beach face. Bars tend to disappear or become discontinuous. During period of high waves the beach face becomes less steep and the bars become more pronounced. This flattening of the beach face, of course, involves cutting back of the berm and temporary steep banks may be formed which seriously impede the operation of amphibious vehicles. Beaches which have formed cusps under the influences of waves arriving parallel to the beach over extended periods, will have these cusps truncated or differently spaced when the wave conditions change. The beach may then have a series of steep escarpments where the crest of each cusp has been cut away, and soft sand newly deposited in the troughs of the old cusps. If the cusps were originally large this may result in very difficult operation conditions. Any beach which is undergoing or has recently undergone a distinct change may be a difficult beach upon which to operate vehicles.

IX. AEROLOGICAL PLANNING FOR AMPHIBIOUS EXERCISES

(Much of the information contained in this section applies to operations in the Southern California area only. When operating in other areas, appropriate substitution of locations and sources of information should be made.)

A. THE OPERATIONAL WEATHER FACTOR

This is defined as the influence exerted by weather and climate on the selection of a landing area and the target date for an amphibious exercise. The applications of the Operational Weather Factor and command decisions based on weather during the conduct of an amphibious exercise are the responsibility of the Officer Conducting Exercise. If aerological personnel are not attached to the staff of OCE, surf, weather and climate information should be requested from the next higher amphibious command in the local area having an aerological unit or, when such services are not available, from the nearest Fleet Weather Central.

B. AVAILABILITY OF AEROLOGICAL SERVICES

An adequate surf and weather forecasting unit for peacetime amphibious exercises consists of an aerological officer, trained in surf forecasting, and one to five aerographers mates. This requirement is met for exercises in the Coronado area by utilizing forecasts originated by COMPHIBPAC. For operations in other localities, if aerological personnel are not regularly attached to the staff of OCE, a request may be directed to COMPHIBPAC for assistance.

C. AEROLOGICAL REQUIREMENTS OF THE PLANNING PHASE

The following planning details are listed for guidance:

1. The operational weather factor and its influence on selection of the landing area and D-Day.

2. Surf and weather information, including reports, forecasts, and observations, required for successful completion of the exercise.

3. Existing weather facilities, including routine weather broadcasts, facsimile map analysis, and local weather forecasts.

4. Special weather facilities, including broadcasts, observations, forecasts, equipment and personnel required.

5. Specific communication channels and times of transmission of weather information.

6. Weather and surf reporting procedures including originator, addressees, time of observation, station designator, weather codes, times of transmission to be used during the operational phases of the exercise.

7. Special weather advisories covering any heavy weather conditions endangering the task force. This will include small craft warnings, gale warnings, storm warnings and hurricane advisories. Dissemination of such weather information to all components of the task force is the responsibility of OCE.

D. SURF FORECASTS

When the exercise inqludes a landing operation the following schedule of surf forecasts is regarded as adequate:

Surf Forecasts (SURFOR);

LOCATION OF EXERCISE	FORECASTER	TIMES OF FORECASTS
Aliso Canyon	Surf and Weather Station Camp Joseph H. Pendleton plus OCE Staff Aerologist when attached.	0800Z 2000Z or as required
*Silver Strand	COMPHIBPAC Aerological Officer plus OCE Staff Aerologist when attached.	0800Z 2000Z or as required
Other West Coast Beaches	OCE Staff Aerologist when attached. Request aerological assistance as necessary from COMPHIBPAC.	0800Z 2000Z or as required

* COMPHIBPAC promulgates surf forecasts for the Coronado Silver Strand Beaches daily.

1. The following elements will be included in the surf forecast:

ABLE - Significant Breaker. The mean value of the 1/3 highest breakers on the beach measured to the nearest half foot.

BAKER - Maximum Breaker. The highest breaker that will be encountered during the forecast period, measured to the nearest half foot.

CHARLIE - Period. To the nearest tenth of a second.

DOG - Type of Breaker. Plunging, spilling, or surging preceded by numerical percent.

EASY - Angle of Breaker with Beach. The angle a breaker makes with a beach in degrees. (The angle will apply from right or left to an observer on the beach facing seaward.)

FOX - Longshore Current. Measured to the nearest tenth of a knot. Transmit direction as set toward direction in which current is moving. (The direction will apply from right or left to an observer on the beach facing seaward).

GEORGE - Number of lines of breakers in surf zone and width of surf zone.

HOW - Remarks.

2. Surf Information (Sample of Surf Forecast)

a. SURFOR 180800Z TO 190800Z X ABLE THREE PNT FIVE X BAKER FOUR PNT ZERO X CHARLIE THIRTEEN PNT ZERO X DOG 40 PLUNGING 60 SPILLING X EASY 5 FROM THE RIGHT X FOX ZERO PNT 5 LEFT SET X GEORGE 2 TO 3 LINES BREAKERS IN 150 FOOT SURF ZONE X HOW DOG 100 SPILLING AFTER 190400Z

b. Surf Observations (SUROB)

The following schedule of surf observations is listed for guidance. The number of observations required will vary with the scope of the exercise.

Type of SUROB	Period	Interval	Observation times
Regular	6 hours	D-4 to D-2	1200Z, 1800Z, 0000Z, 0600Z
Regular	3 hours	D-2 to completion of exercise	1200Z and every 3 hours thereafter
Regular	1 hour	H-12 to H-Hour	
Special		D-2 to completion of exercise	Every time a change of one (1) foot or greater is observed.

The following table indicates availability of service of surf observers in the Southern California area:

Beach Locations	Type of Services	Observers	Request Services From
Aliso Canyon	SURFORS SUROBS	Surf and Weather Station, Camp Del Mar.	Commanding General, Marine Barracks, Camp Joseph H. Pendleton.
Silver Strand, Coronado	SURFORS SUROBS	Attached Aerology unit personnel	Senior Amphibious Command with Aerology unit attached, San Diego.
All Others	SUROBS	UDT and Beachmaster Units Participating in exercise.	Command involved.

E. CONSIDERATION OF SOUTHERLY SWELL ALONG THE CALIFORNIA COAST

It has been found that throughout the months of May through September swell from the Southern Hemisphere dominates the surf at Oceanside, California, almost continuously. Visual observations indicate that this is true for most of that section of California along the coast extending from the Mexican Border north to Long Beach except at certain protected locations. This fact indicates that although statistical wave data obtained from a study of the Northern Hemisphere weather maps may be quite reliable for many locations, it is inadequate for others during certain seasons of the year.

It appears that the present decay curves do not hold when the wave distances are great. The Storm Tracking method, however, appears to give reasonable decay distances, considering the conceivable fetch area that could produce this southerly swell.

The littoral currents, and probably the sand transport, are from south to north in this area during the summer. This fact, together with the continuous nature of relatively high waves should be of prime consideration for harbor development in this area as well as in the planning of military training schedules.

The presence of the southern swell also points to one of the difficulties of wave forecasting by use of weather maps; that is, due to the lack of weather data from the Southern Hemisphere, swell may well appear which has not been forecast. Hence, until weather maps of the Southern Hemisphere are available, local observations should be made of areas of interest to either military or civilian organizations.

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GLOSSARY OF TERMS

1. BAR: An offshore bank of sand, gravel, or other material, especially at the mouth of a river or harbor; or lying parallel to, and a short distance from, the beach. It may obstruct navigation.

2. BEACH FACE: The section of the beach normally exposed to the action of the wave uprush.

3. BERM: The nearly horizontal formation along the beach caused by deposit of material under the influence of the waves. Some beaches have no berms, others have one or several.

4. BREAKER: A wave tripped by shoaling water. The breaker is of the plunging type when the front becomes concave and the crest topples over, appearing to fall vertically. A spilling breaker glides forward without any plunging fall. An offshore wind will favor the development of the hollow front often found in plunging breakers.

5. BREAKER ANGLE: The angle a breaker makes with a beach.

6. CUSP: One of a succession of nearly semi-circular cut-outs occurring along the beach face.

7. DEEP WATER: Where depth is greater than one-half the wave length. Deep water conditions are said to exist when the surface waves are not affected by conditions on the ocean bottom.

8. GRADIENT: The rate of inclination to the horizontal. May be expressed as an adjacent or ratio figure such as 1:25 indicating one unit rise to 25 units of horizontal distance.

9. LITTORAL CURRENT: Currents moving generally parallel to and adjacent to the shoreline.

10. SCARP: An almost perpendicular slope caused by wave action occurring along the shore during periods of erosion.

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11. SEA: Waves caused by wind at the place and time of observation.

12. SHALLOW WATER: Water in which the depth is less than one-half the wave length at the particular time.

13. SURF ZONE: The area between the outermost breaker and the limit of the wave uprush.

14. SWASH: The rush of water up onto the beach following the breaking of a wave.

15. SWELL: The heaving of a body of water into generally smooth waves.

16. WAVE CREST: The highest part of a wave.

17. WAVE HEIGHT: Vertical distance between trough and crest. Usually expressed in feet.

18. WAVE LENGTH: Horizontal distance between successive wave crests measured perpendicular to the crest. Usually expressed in feet.

19. WAVE PERIOD: The time in seconds for a wave crest to traverse one wave length.

20. WAVE STEEPNESS: The ratio of wave height to wave length.

21. WAVE TROUGH: The lowest part of a wave between crests.

22. WAVE VELOCITY: Speed at which the wave form advances across the sea, usually expressed in knots.

[redacted]

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[redacted]

APPENDIX A

This section contains graphical and pictorial examples of subjects discussed in "Surf Manual for Amphibious Planners".

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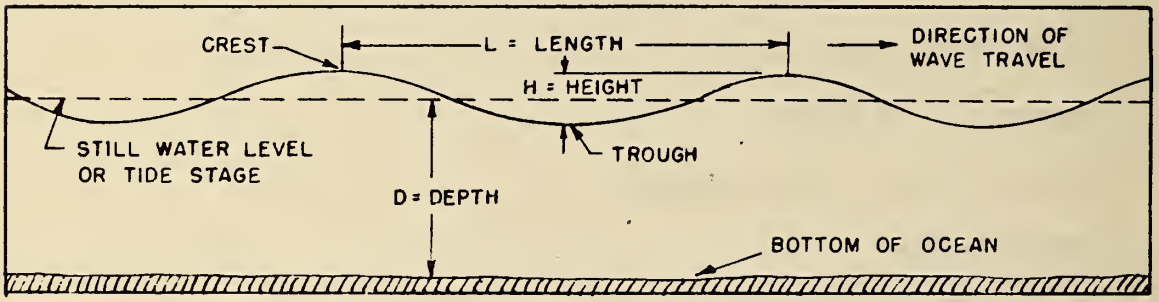
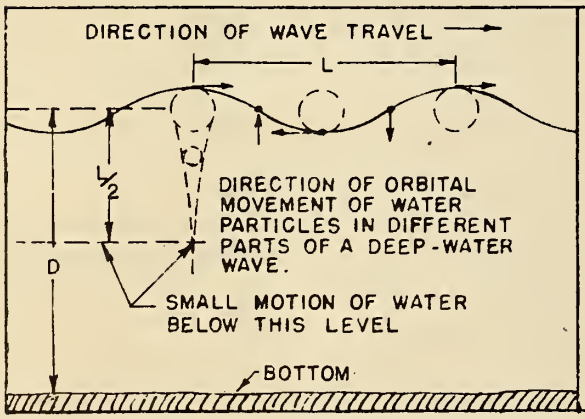
WAVE PROFILE SKETCHES

THE FOLLOWING VERTICAL SECTION SKETCHES ILLUSTRATE THE TERMS COMMONLY EMPLOYED IN DISCUSSIONS OF WAVES, SURF, AND BEACHES

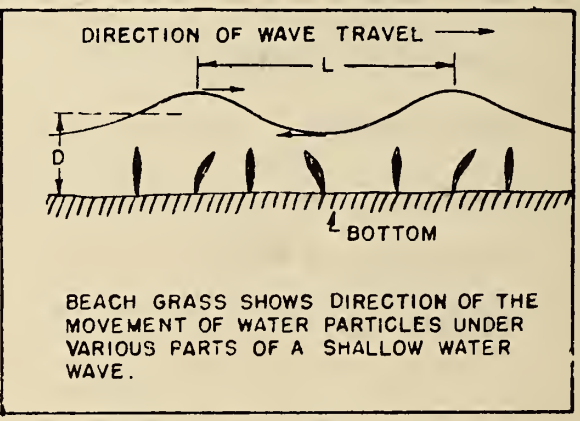


DEFINITIONS OF WAVE CHARACTERISTICS


DIRECTION OF WAVE TRAVEL
L
L/2
D
DIRECTION OF ORBITAL MOVEMENT OF WATER PARTICLES IN DIFFERENT PARTS OF A DEEP-WATER WAVE.
SMALL MOTION OF WATER BELOW THIS LEVEL
BOTTOM

DEEP WATER WAVES

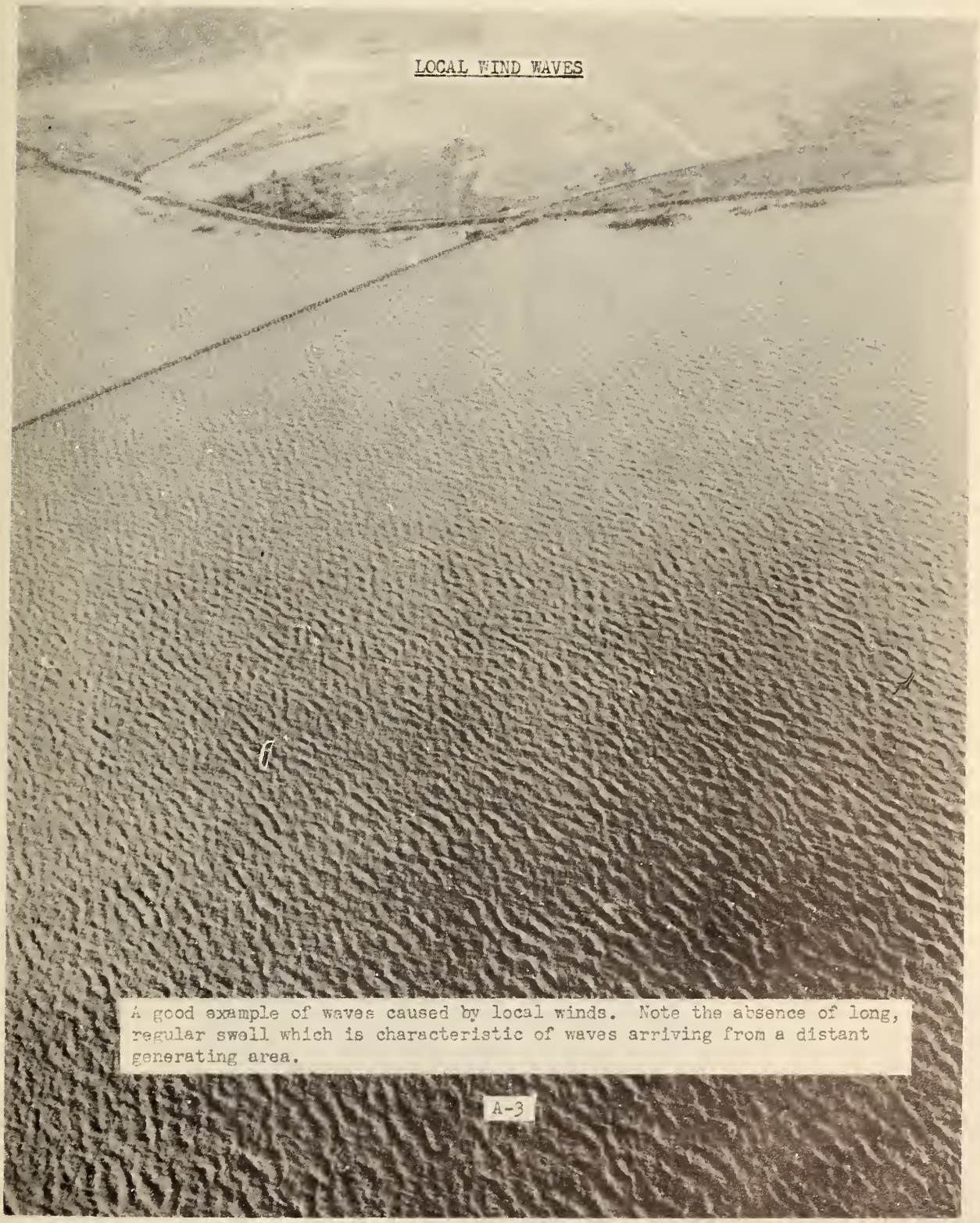
WHEN THE WATER DEPTH IS GREAT, THE BOTTOM HAS NO EFFECT ON THE MOTION OF WAVES; HENCE, SUCH WAVES ARE CALLED DEEP WATER WAVES


DIRECTION OF WAVE TRAVEL
L
D
BOTTOM
BEACH GRASS SHOWS DIRECTION OF THE MOVEMENT OF WATER PARTICLES UNDER VARIOUS PARTS OF A SHALLOW WATER WAVE.

SHALLOW WATER WAVES

WHEN THE WATER DEPTH IS SMALL, WAVES CAUSE THE WATER TO MOVE AT THE BOTTOM.

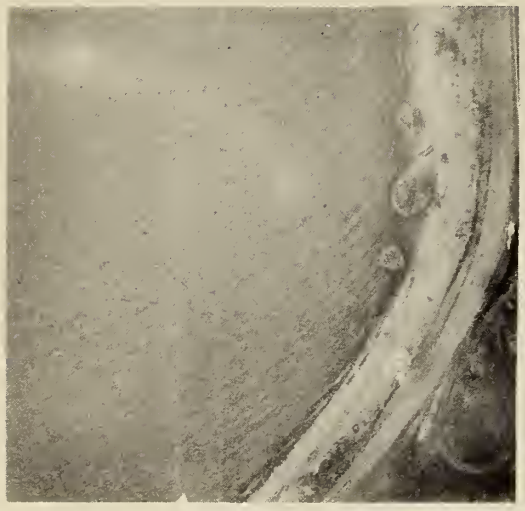
LOCAL WIND WAVES



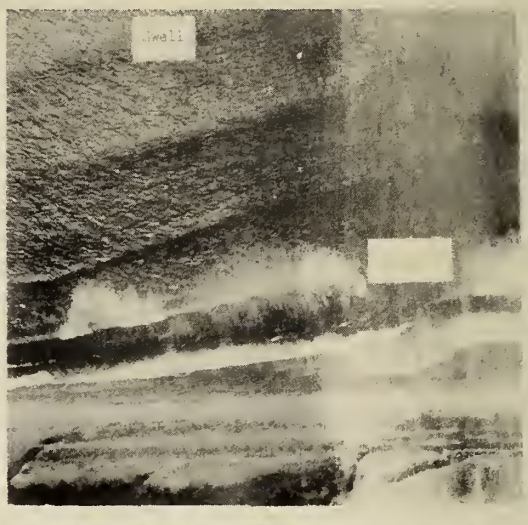
A good example of waves caused by local winds. Note the absence of long, regular swell which is characteristic of waves arriving from a distant generating area.

GENERATION OF WAVES

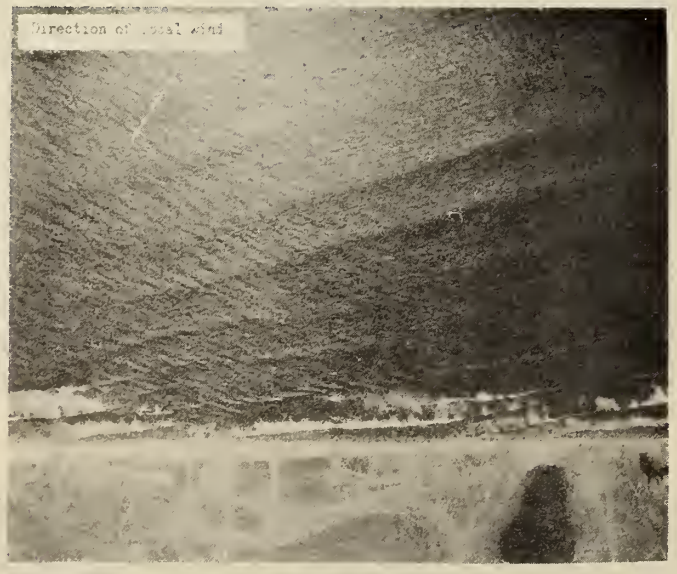
Wavee which affeot amphibious operations are generated by wind blowing over the ocean surface. At first the waves are very small, as shown on the small lake in the photograph below (left). The greater the length of the area over which the wind blows, the longer it blows, and the higher its speed, the larger are the waves. After the waves leave a storm area, as in the open ocean, they tend to become long and smooth "swells" like those shown in the photograph below (right). Eventually the swell reaches shore peaks up and then breaks. It is the larger waves, or swell, breaking on a beach which make the surf dangerous. An aerologist, with the aid of weather charts and hydrographic charts, can forecast the wind blowing over the ocean and then forecast the waves generated by these winds.



Typical wind waves in a generating area. Note the variability of the wave height, wave length, and the length along the crest.



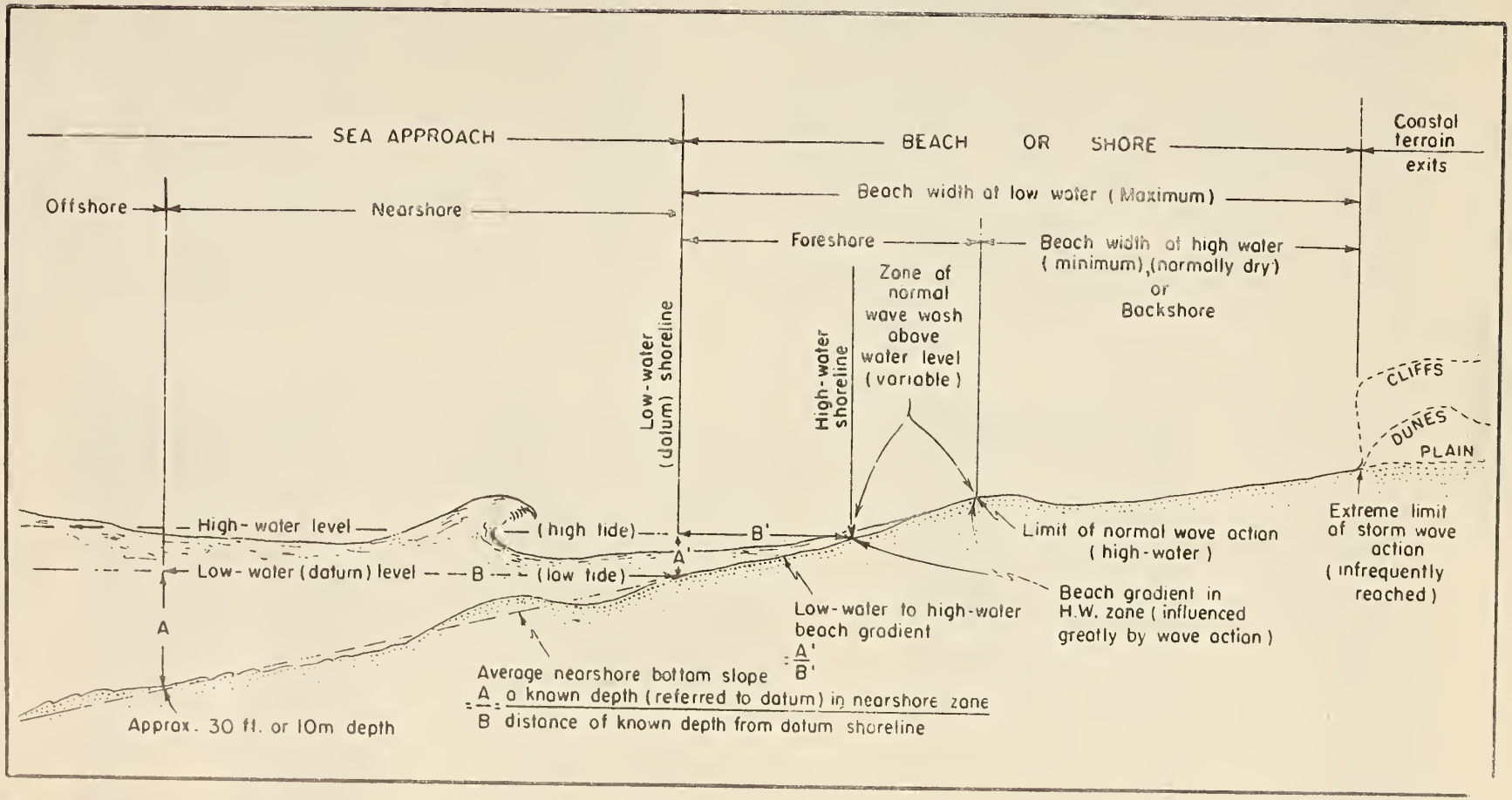
Swell in the vicinity of Oceanside, California resulting from storms thousands of miles to the south. Note the regularity of the swell compared to the waves in a generating area, as shown in the photograph to the left.



Aerial Photograph Showing Two Wave Trains.

The small waves coming from the upper right are being generated by the local wind. The long low swell from the upper left was generated several thousands of miles away. Note that the swell is almost invisible in deep water but peaks up near shore to form the predominant breakers.

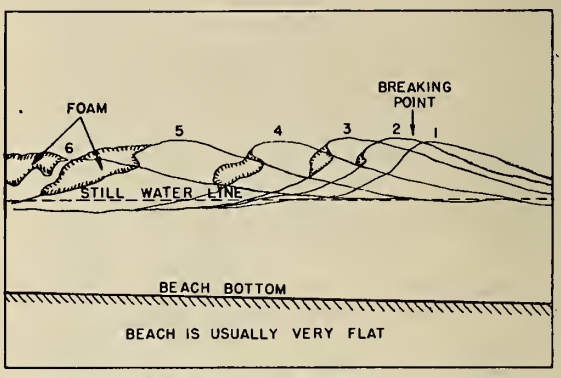
GENERAL BEACH PROFILE DIAGRAM


SEA APPROACH
BEACH OR SHORE
Coastal terrain exits
Offshore
Nearshore
Beach width at low water (Maximum)
Foreshore
Beach width at high water (minimum), (normally dry) or Backshore
Low-water (datum) shoreline
High-water shoreline
Zone of normal wave wash above water level (variable)
CLIFFS
DUNES
PLAIN
High-water level
(high tide)
B'
A'
Low-water (datum) level
B
(low tide)
A
Limit of normal wave action (high-water)
Extreme limit of storm wave action (infrequently reached)
Beach gradient in H.W. zone (influenced greatly by wave action)
Low-water to high-water beach gradient = A'/B'
Average nearshore bottom slope = A/B = a known depth (referred to datum) in nearshore zone / distance of known depth from datum shoreline
Approx. 30 ft. or 10m depth

BREAKER TYPES

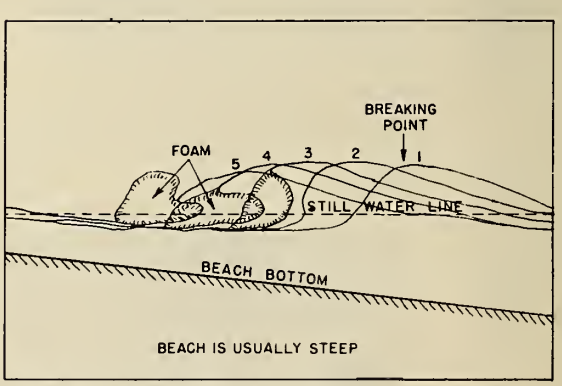
Both photographs and diagrams of the three types of breakers are presented below. The sketches consist of a series of profiles of the wave form as it appears before breaking, during the breaking, and after breaking. The numbers opposite the profile lines indicate the relative times of the occurrences.

SPILLING BREAKER



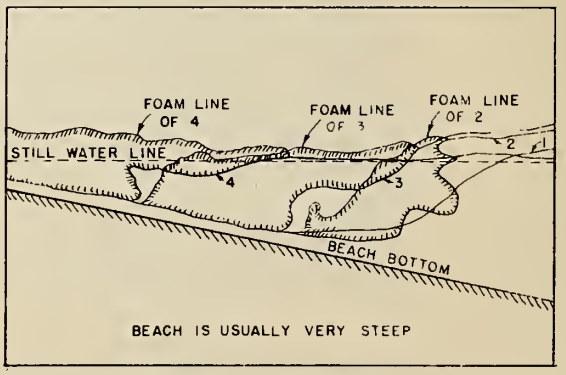
SKETCH SHOWING THE GENERAL CHARACTER OF SPILLING BREAKERS

PLUNGING BREAKER



SKETCH SHOWING THE GENERAL CHARACTER OF PLUNGING BREAKERS

SURGING BREAKER



SKETCH SHOWING THE GENERAL CHARACTER OF SURGING BREAKERS

BREAKER TYPES - EFFECT ON CRAFT

Surging Breaker at Blue Beach,
Operation Miki, Oahu, T. H.

Surging Breaker at Yellow Beach,
Operation Miki, Oahu, T. H.

Surging breaker at
Blue Beach, Operation Miki,
Oahu, T. H.

Seven Foot Plunging Breaker,
Monterey, California

Plunging Breaker. LCM in 14 Foot Breaker

Spilling Breaker. LVT(3)(C) in 6 Foot Breaker.

Plunging Breaker. Dukw in 15 Foot Breaker

Spilling Breaker. LVT(3)(C) in 8 Foot Breaker.

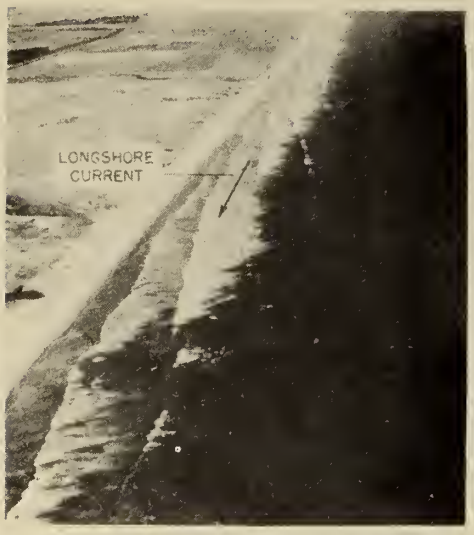
Plunging Breaker. Enlargement of Above

Spilling Breaker. LVT(3)(C) Nearly Covered by 10 Foot Breaker. Vertical photo

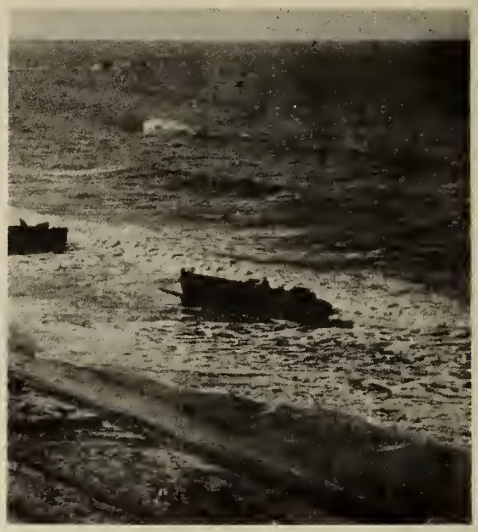
Example of wide surf zone with numerous lines of breakers. Effect of refraction, caused by non-parallel bottom contour lines, is also evident in this photograph.

LONGSHORE CURRENT

A longshore current is set up within the surf zone when waves break at an angle with the shoreline. The currents flow parallel to the shoreline inside the breaker zone and are found most commonly along straight beaches. Their velocity increases with increasing breaker height, decreasing wave period, increasing angle of breaker-line with the beach, and increasing beach slope. The longshore current is much less than the velocity of the oscillating currents but it is relatively constant in direction with sustained velocities as high as three knots having been measured. Normally, velocities of from 1/4 to one knot can be expected. Strong longshore currents are effective in causing landing craft to broach.



Aerial photograph of swell breaking at an angle to the shoreline, thus causing a longshore current in the direction shown.

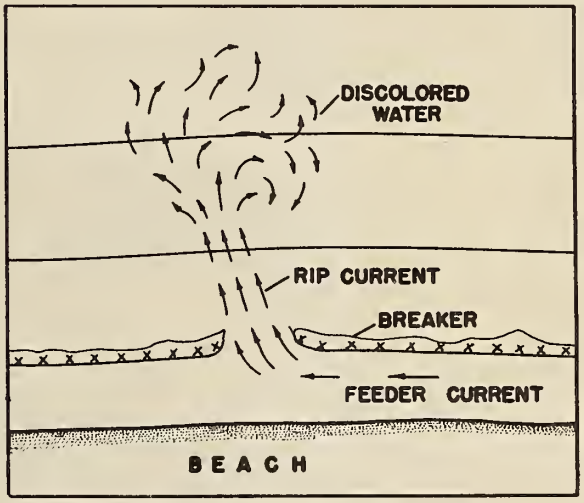


Photograph of landing craft broached as a result of the longshore current.

Some difficulty was encountered while attempting to drive jeeps from LCVPs which were careened by the surf, sometimes violently, endangering personnel. An attempt was made to steady and straighten out the craft by hawsers held by men on the beach. (Notice man standing between the jeep and side of LCVP.) November 25, 1946

RIP CURRENTS

A type of current in the surf zone that may be of importance in certain areas is the rip current. Rip currents flow out from shore through the breaker line in narrow rips and occur on almost all open coasts. They are caused by the waves piling water against the coast. This water flows along shore until bottom irregularities are such that it can escape seaward. As indicated by the following photograph, a rip current consists of three main parts: the feeder current, which flows parallel to the shore inside the breakers; the rip current proper, which flows through the breakers in a narrow band; and the seaward portion, where the current widens and slackens. Rip currents are easy to detect from the air but more difficult to detect from the ground. A ground observer usually can distinguish a rip by a stretch of unbroken water in the breaker line and patches of foam and discolored water offshore. Once rip currents have formed, they cut troughs in the sand and remain fairly constant in position until the wave conditions change. It has been found that, as rip currents cut channels through bars, it is usually best to operate LCM's and LCVP's in these rips during low tides as then there is less chance of the craft becoming stuck. On the other hand, experience has also shown that it is best not to operate LVT's and Dukws in rip currents.

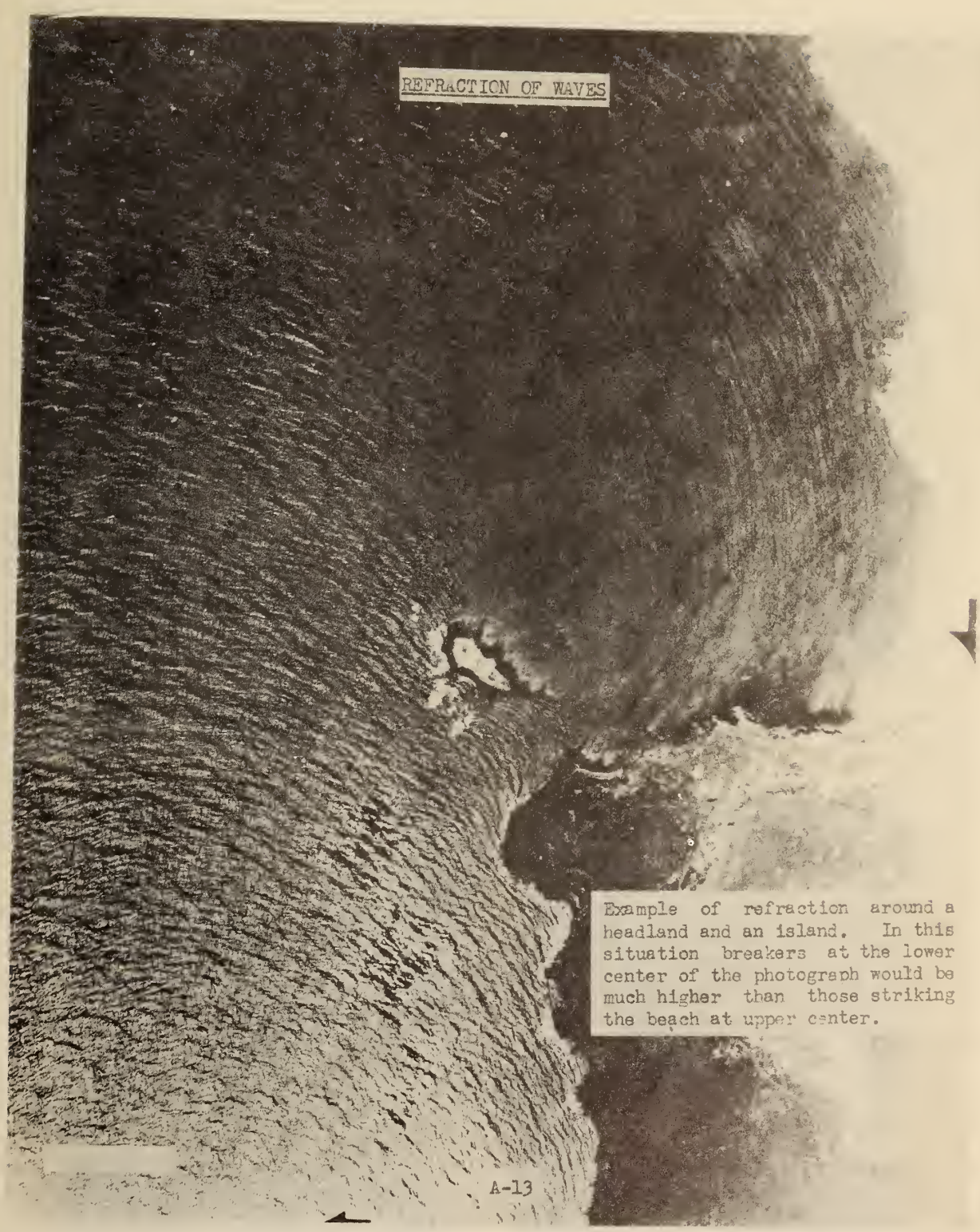


Idealized Rip Current
The Feeder Current may, and often does, approach from both sides.

Aerial Photograph showing Rip Current

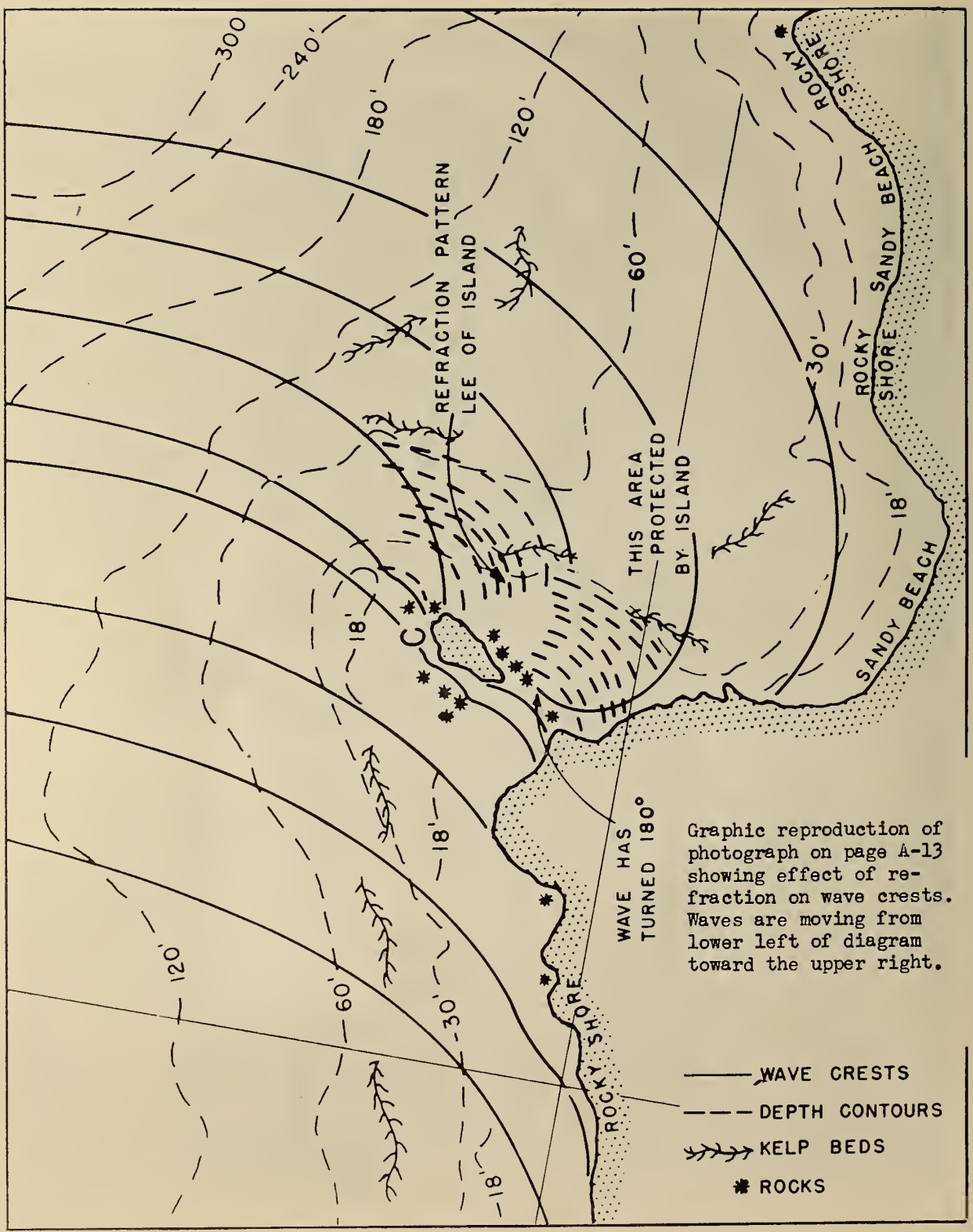
CUSPS

A good example of cusps, caused by breakers striking a beach at an angle.



Example of refraction around a headland and an island. In this situation breakers at the lower center of the photograph would be much higher than those striking the beach at upper center.

REFRACTION OF WAVES

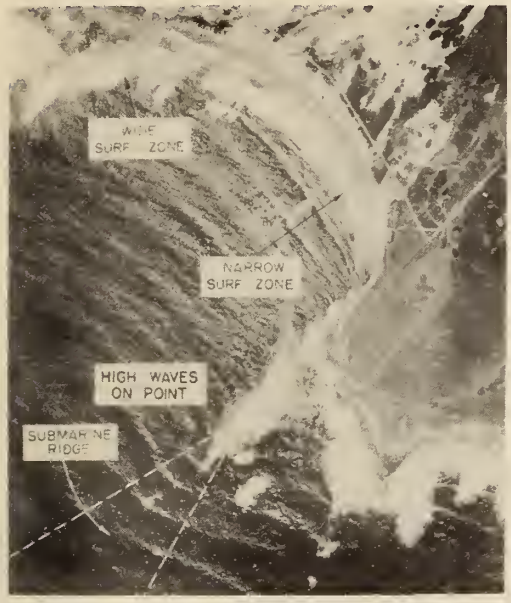


Graphic reproduction of photograph on page A-13 showing effect of refraction on wave crests. Waves are moving from lower left of diagram toward the upper right.

REFRACTION OF WAVES

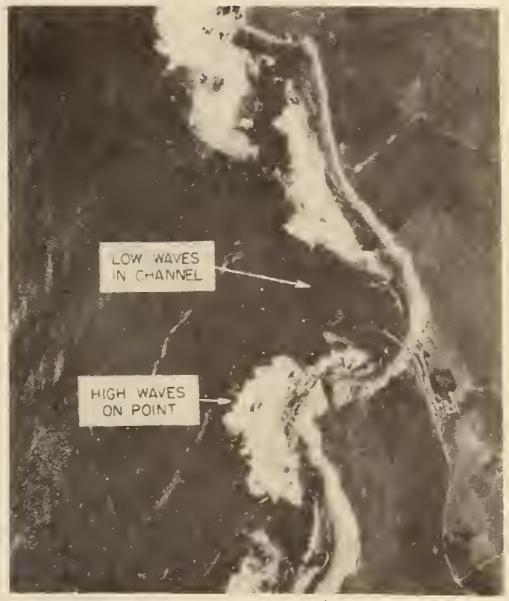
SHOALING BOTTOM

As waves move into shallow water and approach the shore at an angle to the bottom contours, the waves are bent. This is known as refraction. The bending of waves may cause a converging or diverging of the crests (depending upon the hydrography) with a subsequent increase or decrease in wave or breaker height. Another effect of waves approaching a beach at an angle is to induce a longshore current inside the breaker zone. This current is effective in transporting sand along the shore and is also a hazard to landing craft operating through the surf zone.



Pt. Pinos, California

Waves moving over a submarine ridge concentrate to give large wave heights on a point.



Arena Cove, California

Spreading of waves by refraction produces low wave heights at the pier.

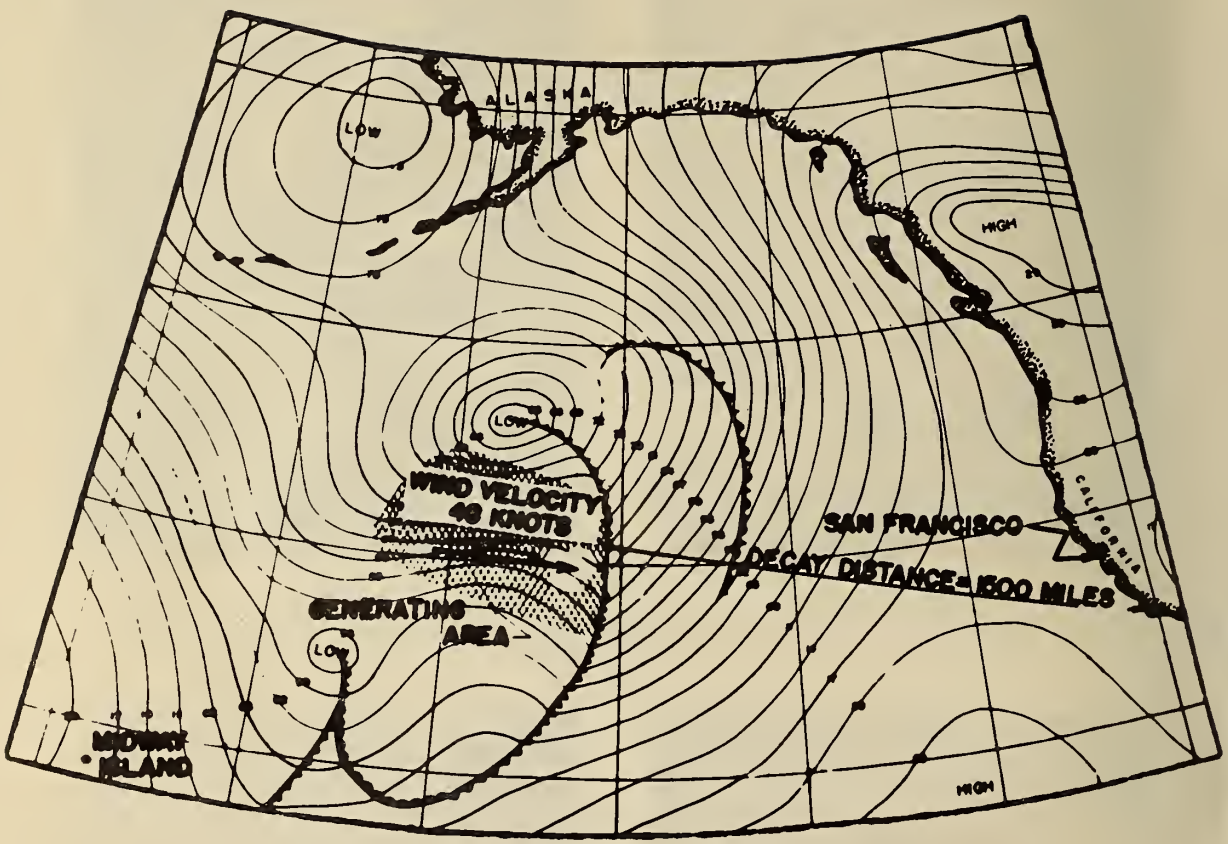
Halfmoon Bay, California

Note the increasing width of the surf zone with increasing degree of exposure to the south.

Purisima Pt., California

Refraction of waves around a headland produces low waves and a narrow surf zone where bending is greatest.

WEATHER MAP



A TYPICAL WEATHER MAP SHOWING A GENERATING AREA AND DECAY DISTANCE

In this situation the westerly winds in the generating area are producing waves which will move toward the California Coast. Their passage through the 1500 mile decay area will alter their characteristics in the following manner: wave period will increase, wave length will increase, and wave height will decrease.

[redacted]

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